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ELECTRICAL SECTION.

Stated Meeting, held Thursday, December 19, 1901.

PARALLEL OPERATION OF ALTERNATORS.

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Some time during the month of November, 1900, the writer conceived an idea for a device which would indicate synchronism between two alternators about to be thrown in parallel. The idea seemed to promise far better results than anything used before, and a model which was constructed and put in operation about January 1, 1901, bore out this anticipation. The attention which the instrument attracted from the electrical engineering profession was thought to be sufficient to justify submitting it to the Franklin Institute for examination. Correspondence with the commitee appointed by the Institute on the question to whether or not it was desirable for me to come to Philadelphia to explain its workings in detail, finally cul-

minated in an invitation to read a paper covering the general subject of the operation of alternators in parallel.

I am well aware that much has been written on this subject, and that it is not likely that my discussion will bring out anything new. My treatment, however, may enable some of you to look at this subject from a new viewpoint.

It is fortunate that we possess a mechanical analogy that, in many respects, gives an exact representation of alternators in parallel. In place of a bank of alternators taking mechanical power from their prime movers and supplying electrical power to a common bus bar, substitute a bank of spur gears also taking power from prime movers and supplying it through these gears to a common shaft. This line shaft is the mechanical analogue of the bus bars, and the spur gears of the alternators. At the bus bars is available in shape of electrical energy transmitted through dynamos all the power of the various prime movers. Similarly, at the line shaft, is available in the shape of mechanical energy transmitted through spur gears all the power of the various prime movers.

Successful operation of alternators in parallel consists:

(1) of proper division of load; and

(2) of freedom from hunting.

The first of these headings may be again subdivided into:

(*a*) Alternators driven by a common prime mover; and

(*b*) Alternators driven by separate prime movers.

The only case of alternators driven by a common prime mover that deserves consideration from its practical use is that of alternators' belt connected to a common line shaft. In this case division of load is a matter of pulley ratio and of tightness of belt. This problem is exactly the same as that of division of load among a number of belts that are taking mechanical power from one line shaft and delivering it to another. In both cases the division of power depends upon pulley ratio and relative condition of belts.

The real problem of proper load division, however, comes under the second heading. In this case the analogy between alternators and gears is perfect. In the case of the gears,

relative load taken by prime movers is, of course, dependent entirely on conditions outside the gears. Just so the division of load between prime movers driving alternators, and, consequently, between the alternators is entirely dependent on conditions outside the alternators. That is, there is no adjustment of field or other conditions of an alternator which will make a change in the relative amount of load supplied through that alternator—unless the alternator is forced out of step. This condition is comparable in our analogue to the stripping of the gear, and is a condition which occurs under abnormal circumstances. To those whose experience has been entirely with the parallel operation of direct-current dynamos, the idea of field adjustment having no effect on relative load may at first seem somewhat startling. The mechanical analogue of direct-current machines in parallel is the connection of the various prime movers to the line shaft by belts, or other friction connection, where an addition of load produces a slip. Stiffening the field is like tightening the belt. The tendency of either stiffening the field of one of a bank of parallel connected direct-current dynamos, or of tightening the belt of one of a bank of belt-connected prime movers driving a common counter-shaft is to slow down that prime mover. The governor in correcting this tendency causes the prime mover to assume a larger share of the load. With the alternator, however, the case is different. Prime movers, driving a bank of parallel connected alternators, are practically geared together, and any condition which effects the speed of one effects the speed of all similarly and simultaneously. It will be at once recognized, therefore, that the problem of successfully operating alternators in parallel is a problem of governors, and not a problem of alternators.

Governors must control speed with respect to load, in one of three ways:

(1) Speed may rise with increasing load.

(2) Speed may be independent of load, and

(3) Speed may fall with increasing load.

Proper division of load occurs between parallel connected alternators only when the prime movers are provided with

governors of the third type. A moment's consideration will show that equilibrium between the loads of parallel connected alternators cannot be maintained with either of the first two types; for if two or more prime movers, each provided with a governor of the first type, are connected by gear or alternator to a common load, the prime mover, whose governor first responds to an increase in load—it being impossible to so adjust the governors that they will all respond simultaneously—takes the entire load increase. The increase of load being thus taken care of, the governor of the prime mover, which has assumed the increase, demands for a condition of equilibrium a speed higher than the original; that prime mover will, therefore, assume another increment of load and tend to raise the speed to a higher level. This tendency to a higher speed will, of course, bring into action in a contrary direction some of the remaining governors. The net result will be that some alternators would be delivering the maximum power of their prime movers; others would be taking power from the bus bars to turn their prime movers, and one would be somewhere between these two limiting values.

In the case of a governor which regulates speed entirely independent of load—the case practically of the isochronous governor—there would exist neither the tendency to entire absence of equilibrium, as under the first-mentioned type of governor, nor the tendency toward perfect equilibrium as under the third-mentioned type. It is impossible, however, to adjust all governors to the same degree of sensitiveness. In a bank of parallel connected alternators, therefore, there is nothing to prevent that alternator and prime mover with the most sensitive governor from continuing to assume all load changes until the limiting load of its prime mover is reached.

It is, therefore, only with the third type of governor—where speed falls as load increases—that proper division of load between alternators connected in parallel can be attained. It is with this type of governor only that the maximum loaded prime mover tends to assume all decrements of load, and the minimum loaded prime mover tends to assume all increments of load.

In regard to the per cent. drop in speed between no load and full load required to bring about proper load division, I can only quote my own experience with the turbines and dynamos of the Niagara Falls Power Company. In this case the speed drops about 2 per cent. between no load and full load, and the difference between the loads taken by various turbines rarely amount to more than 10 per cent. of a single unit's output.

There are other methods of insuring a proper load division, but they are open to such objections that they are not generally employed. One method is to actuate all governing mechanisms from a single master governor. This necessitates some connection, either mechanical or otherwise, between all the governors in use. Another method is to set in a fixed position all governors but one, allowing that one to take all load changes. In this method no attempt is made to equalize loads, and it might lead to disastrous results in case the entire load is suddenly removed.

Proportional division of load, while desirable, is not an absolute essential to the successful operation of many plants. Freedom from hunting, on the other hand, is an essential; and where hunting exists to any pronounced extent, successful parallel operation is impossible. Further, hunting is a fault which may arise not only with alternators in parallel, but in any electric circuit containing two or more synchronous machines, be they alternators, synchronous motors or rotary transformers.

Before discussing the causes of hunting, let me say a few words in regard to the reactions which occur between the field and armature of an alternator. Each time a given point on an alternating armature passes a pair of poles, the armature voltage passes through a complete cycle. That is, the voltage has passed from a maximum in one direction to a maximum in the other, and has returned to the point from which it started. Let this point of the armature be so selected, that when there is no load it passes the center of the pole-pieces at the instant the armature voltage is passing through zero. If, now, the position of this point relative to the center of the pole-pieces be examined when the alterna-

tor is under load, it will be found in the case of a dynamo ahead of and in the case of a synchronous motor back of the center of the pole-piece at the instant voltage is passing through zero. The amount of this movement depends, first, upon the amount and character of the load, and second, upon the regulation of the alternator. That is, the load-current in the armature combines with the field-current, and their resultant field takes up a new position which, in a generator, is in the direction of armature motion, and in a motor in a contrary direction. In other words, a mechanical strain on an alternator armature produces a mechanical displacement. Our mechanical analogue of the gears fits this aspect of the alternator if we replace the inflexible rigid gear tooth with an elastic flexible one, as, for instance, one of soft rubber. The greater the strain on this rubber toothed gear the greater will be the distortion of the teeth in contact. In the alternators the pressure between teeth is a current in the armature, and distortion of the gear teeth is a distortion of the alternator field. In either case we have both the prime conditions necessary for an oscillating system—a mass free to move and an elastic force which tends to return that mass to its original position in case of displacement. Hunting in synchronous machines is simply the oscillation of the armature masses accelerated and retarded above and below normal average speed. The problem of preventing such hunting is, therefore, the problem of causing a pendulum to cease swinging. A pendulum to continue swinging must have:

(1) An active force, synchronous with the pendulum swings; and

(2) Freedom to move without undue friction.

Hunting of parallel connected alternators, like the swinging of a pendulum, will die out if not kept alive by some synchronous force. Also hunting of alternators in parallel like the swinging of a pendulum may be kept alive and even made violent by an exceedingly small synchronous force, provided movement can take place without undue friction. It is evident, then, that the two lines of attack to prevent hunting are:

(1) The removal of the synchronous force tending to keep alive the oscillatory motion, and

(2) The provision of electric friction tending to destroy such motion if once started.

Probably the most potent factor in keeping alive hunting will be found in the steam-engine governor as usually installed. The slight acceleration and retardation that hunting causes in the speed of the prime mover is sufficient to throw the governor into action, particularly if the governor is of a type in which inertia plays a prominent part. The delay in time between speed change and the corrective force applied by the governor is enough to cause a part, at least, of this corrective force to alternate synchronously with the speed changes. That is, hunting induces or tends to induce in certain governors a synchronous force to keep itself alive. The remedy to this action is to make the time between a movement of the governor balls and its application of the corrective force greater than the time of a half-cycle in the period of oscillation. That is, to prevent hunting, the period of oscillation should be decreased and the time of response to motion of governor balls increased. The period of oscillation is decreased by reducing the mass of alternator armatures and by increasing their synchronizing force or, what is the same thing, stiffening their regulation. For a plant already in operation, however, these quantities are fixed, and in any event there is a limit to the time-period of oscillation even with the most favorable design, which may bring it within time of response to motion of governor balls. A remedy then involves the prolongation of the time of response to motion of governor balls. This object may be accomplished by the aid of properly designed dash-pots. Mr. W. L. R. Emmett, of the General Electric Company, in a very able paper read by him before the American Institute of Electrical Engineers, on October 25 1901, described an ingenious dash-pot which he has designed and repeatedly used with success in connection with engine governors for the suppression of hunting. In that paper Mr. Emmett states that his dash-pot has suppressed hunting in every case where it has been applied,

even though the hunting was so severe before its application that parallel operation was impossible.

This action of the governor, however, is not the only force which may give the synchronous impulses necessary to keep parallel connected alternators hunting. The uneven torque at different points in an engine-cycle may give rise to hunting if the natural period of oscillation is synchronous with the engine impulses. One remedy for this difficulty is to synchronize engines as well as alternators, so that at any instant of time each engine is in a similar part of its cycle. Another remedy lies in the addition of fly-wheel capacity, which will tend to absorb and smooth out the mechanical fluctuations which must otherwise appear as fluctuations in load between alternators. There are other forces which may, under certain circumstances, become sufficient to account for hunting, and which will be discussed later.

The second preventive for hunting lies in so designing the alternating machines that as soon as hunting occurs a resisting force of a frictional nature is set up tending to destroy the oscillation. This remedy is like floating the pendulum bob in oil or water. This electric friction is introduced by surrounding the field poles, especially near the tips, with a band of copper. The change in field flux, caused by the distortion of hunting, produces eddy currents in this copper band. Still better is a copper plate which projects under the pole tips. The shifting of magnetic flux to and fro across the pole face while hunting is more pronounced than the total variations in that flux, and this flux change is a maximum at the pole tip. Consequently, the copper pieces under the pole tips, or in fact any conductors so placed that the shifting field produces eddy currents therein, are better adapted to produce the desired damping effect than is the short circuiting band. With a solid pole-piece the metal of the pole-piece itself forms a path for the eddy currents, and it has always been noted that the performance of solid pole alternators is better, so far as freedom from hunting is concerned, than laminated pole alternators where the poles are without the

protection described above. It is evident, however, that a complete remedy cannot be obtained by the damping method alone. So long as there is a force tending to produce oscillations, hunting will exist. In any case the amplitude of the oscillations will be such that the energy absorbed by them is equal to the energy producing them. Damping, therefore, means simply a reduction of the amplitude and not a complete suppression of the oscillation. To complete the cure not only must the damping or friction element be introduced, but the tendency to produce oscillation must be removed.

My experience has included a few cases of hunting on circuits in which the prime movers were turbines and the governors were of a relay type where response to motion of governor balls required several seconds—much longer than the time of a half-period of the hunting. In these cases the hunting can be ascribed neither to the irregularity of torque in the prime mover, nor to the action of the governor. In all of these cases which have come under my observation, some part of the electric system—not necessarily, however, that in which hunting was most noticeable—contained synchronous machines with laminated poles and no damping pieces. That is, these machines were capable of maintaining hunting oscillations with an exceedingly small synchronous force. As an example of the minute power to keep alive an oscillation where there is no damping, witness the clock in which a few foot-pounds of energy in a coiled spring keeps the pendulum oscillating for days and even for weeks. The small amount of power required to account for the hunting above mentioned is, undoubtedly, due to the fact that the power in an alternator is delivered as a series of impulses—not as a steady push. During one-half of a complete hunting oscillation these impulses tend to accentuate such oscillation, and during the next succeeding half-oscillation, to suppress the oscillation. If the time of a complete oscillation is exactly equal to the time of any odd number of impulses, the sum of impulses for accentuation may be one impulse greater than the sum of impulses for suppression of the oscillation. It

may thus occur that where resistance to oscillation is slight, hunting is kept alive by the fact that the power of the prime mover is delivered as a series of impulses, and not as a steady push. It may be objected that in polyphase alternators the instantaneous amount of power is always a constant. This is true for the summation of power from all phases, but is not true for the individual phases which go to make up that summation. That this explanation is the correct one is indicated by the fact that the hunting referred to above was invariably suppressed by changing the field strength. Changing the field strength by changing somewhat the elastic force operating upon the armature causes in turn sufficient variation in time period of oscillation to throw it out of step with its exciting force.

A paper on the parallel operation of alternators would hardly be complete without some discussion of the methods and apparatus used for throwing alternators in parallel. Particularly is this true, in the present case, where the writer's device for synchronizing alternators is directly responsible for the presentation of this paper.

Both spur gears and alternators must be properly synchronized before throwing them into service. In the case of spur gears, before throwing them into mesh they must not only be brought to practically the same speed, but the instant for throwing into mesh must be so chosen that a tooth of one is exactly opposite a space between teeth of the other. If either of these requisites be neglected there is considerable danger of stripping a gear. The alternator is very similar. Before paralleling alternators, not only must the frequencies be practically the same, but the instant for paralleling must be so chosen that the E.M.F. waves are in practically the same phase relation. That is, the two E.M.F. waves must pass through zero in a certain direction at practically the same instant of time. If either requisite be neglected there is considerable danger that the alternator will fail to fall into step.

The standard methods of synchronizing alternators are:

(1) The use of synchronizing lamp.

(2) The use of synchronizing voltmeters, and

(3) Woodbridge's method.

All three of these methods depend upon the fact that a change of phase relations between two E.M.F.'s causes a change in the resultant voltage obtained by combining the two E.M.F.'s. If the angle between any two radii of a circle represents the phase angle between two E.M.F.'s, the chord joining the outer ends of the radii represents the resultant of the two combined E.M.F.'s. A resultant voltage of zero, therefore, indicates that the two E.M.F.'s are in phase. A lamp, or voltmeter, which will indicate when this zero voltage occurs, will indicate also that the difference in phase between the two E.M.F.'s is zero. The principal difficulty with this method is that no alternating voltmeter responds to less than 20 per cent. of its normal scale, and an incandescent lamp will not begin to glow until about 40 per cent. of its normal voltage is reached. That is, the limits of sensitiveness of synchronism by voltmeter is about 25° each side of zero phase difference and by lamps nearly 50.° Inside these limits the operator has no indication of phase difference except what he can judge by interpolating between equal lamp brightness or equal voltmeter readings. With unsteady and constantly changing speeds such interpolation becomes both difficult and dangerous. Still further inaccuracies arise from the sluggishness with which a lamp filament follows a change in voltage, and in the case of some voltmeters from the fact that they are far from dead heat.

It is very often the custom to reverse one of the voltage components so that zero phase difference is indicated with a maximum resultant and not with a zero resultant; or, in other words, the two E.M.F. components have a phase difference of 180° instead of 0° when synchronism exists between the two armatures. The gain in sensitiveness, however, is slight, for the reason that at and near the point of maximum resultant voltage it requires a large phase change to cause a noticeable resultant voltage change. A decrease of one per cent. for instance, from the maximum resultant voltage occurs only when the two components have departed from their in phase position by nearly 20.°

A very ingenious method has been devised by Mr. J. E.

Woodbridge, which overcomes the lack in sensitiveness inherent in the methods described. Woodbridge's method is applicable only to polyphase alternators, and particularly to three phasers. The method consists of combining two E.M.F.'s which have a phase difference other than 0° or 180° when the alternator armatures are in synchronism. Thus in a three-phase system two E.M.F.'s are combined whose phase angle is 60° at the instant the alternators are in synchronism. The resultant voltage is equal to each of the components when these components are equal, and to nearly an average when they differ slightly. This modification not only brings the voltmeter reading at synchronism within the sensitive range of the voltmeter but also causes synchronism to occur at a period in the cycle of phase change where variations in the phase angle are proportioned to variations in voltage. The objection to the method is that there are two points in the cycle of phase change where a voltmeter thus connected will indicate apparent synchronism. One of these points is true synchronism and the other 120° from synchronism. It becomes necessary, therefore, to provide an additional indicator that will tell which of these two points is the correct one.

All the foregoing methods employ a device sensitive to change in voltage for the real purpose of measuring a phase relation. The methods are indirect, in that they indicate resultant voltage which is dependent upon phase relations and do not attempt to indicate the phase relation itself. My device attacks the problem directly, being a true phase indicator and is independent of relative values of the two E.M.F.'s, whose phase relation it indicates. Outwardly this synchronizer consists of a hand which revolves around a dial, just as the hand of a clock revolves around its dial. *Fig. 1* gives a view of the instrument. When in operation the angle between the hand and its printed image is always equal to the phase angle between the E.M.F. of the bus bars and that of the incoming alternator. If the incoming alternator is running too fast the hand rotates clockwise, and if too slow counter-clockwise. One revolution of the hand clockwise, therefore, means a gain of one cycle by

the incoming alternator over the bus bars; while one revolution counter-clockwise indicates a loss of one cycle. In other words, a single revolution clockwise or counter-clockwise indicates that the incoming alternator is relatively one pair of poles ahead of or behind the alternators with which it is to be paralleled. The following description of the instrument is an extract from a paper read by me before

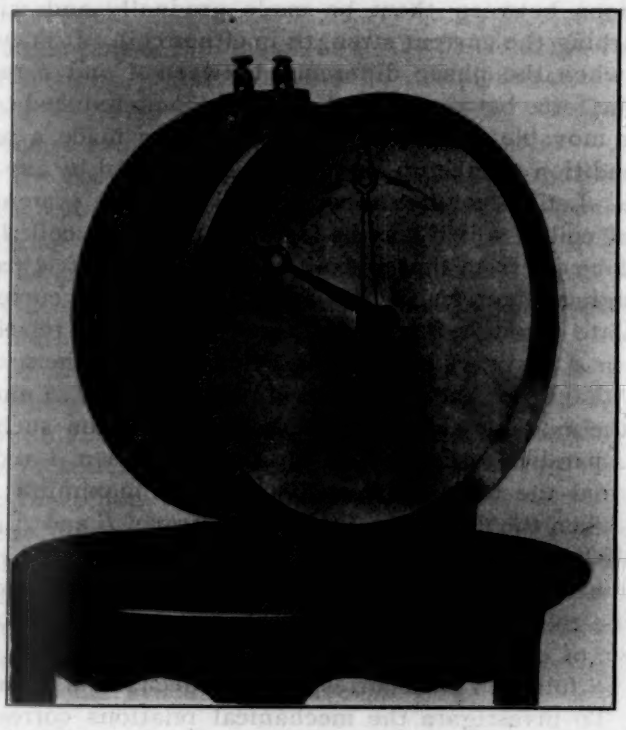

FIG. 1.

the American Institute of Electrical Engineers, August 21, 1901:

"Suppose a stationary coil *F* has suspended within it a coil *A*, free to move about an axis in the planes of both coils and including a diameter of each. If an alternating current be passed through both coils, *A* will take up a position with its plane parallel to *F*. If now the currents

in A and F be reversed with respect to each other, coil A will take up a position 180° from its former position. Reversal of the relative directions of currents in A and F is equivalent to changing their phase relations by 180°, and, therefore, this change of 180° in phase relations is followed by a corresponding change of 180° in their mechanical relations. Suppose, now, that instead of reversing the relative direction of currents in A and F, the change in phase relations between them be made gradually and without disturbing the current strength in either coil. It is evident that when the phase difference between A and F reaches 90° the force between A and F will become reduced to zero and a movable system, of which A may be made a part, is in condition to take up any position demanded by any other force. Let a second member of this movable system consist of coil B, which may be fastened rigidly to coil A, with its plane 90° from that of coil A, and the axis of A passing through a diameter of B. Further, suppose a current to circulate through B whose difference in phase relative to that in A is always 90°. It is evident under these conditions that when the difference in phase between A and F is 90°, the movable system will take up a position such that B is a parallel to F, because the force between A and F is zero, and the force between B and F is a maximum; similarly when the difference in phase between B and F is 90°, A will be parallel to F. That is, beginning with a phase difference between A and F of O, a phase change of 90° will be followed by a mechanical change in the movable system of 90° and each successive change of 90° in phase will be followed by a corresponding mechanical change of 90°. To investigate the mechanical relations corresponding to intermediate phase relations, suppose the phase difference between A and F to be O. The force between A and F will then be a maximum, and that between B and F, O. Now, suppose a small change in phase between A and F to take place. The force between A and F becomes slightly less than the maximum, and that between B and F becomes other than O. The movable system will take up the position of equilibrium between

forces on *A* and *B*, which will be somewhere intermediate between *A* parallel to *F*, and *B* parallel to *F*. It is further evident that the direction of motion of the movable system depends upon the sign of the differential change, so that such a device is not only responsive to a change of phase between *A* and *F*, but is also responsive to the direction of that change.

"It may be interesting to note that quadrature between *A* and *B* is not absolutely necessary either in the mechanical angle between *A* and *B*, or in the phase angle between their currents. So long as there is a displacement between *A* and *B*, both mechanical and electrical, the device is responsive to phase changes between *A* and *F*.

"The above is a brief description of the principles upon which rests this new synchronism indicator. Connect coil *F* to a set of bus bars, and coils *A* and *B* to a dynamo that is to be parallel to those bus bars, and in the motion of movable coils there is a constant index of the phase condition of the dynamo with respect to the bus bars. . . .

"In the commercial construction of the device a laminated iron magnetic circuit is used and the phase difference between *A* and *B* is secured by using a non-inductive resistance in series with one coil, and an inductance in series with the other. It is, of course, impossible to secure 90° phase difference in this manner, but sufficient difference can be obtained to answer all practical purposes. Current is introduced into the armature through three slip rings, one of the rings being made to do duty for one end of both armature windings.

The ideal synchronizing device should perform three functions.

(1) It should tell the amount of difference in frequency.

(2) It should tell whether the machine being synchronized is running too fast or too slow.

(3) It should tell the exact point of synchronism.

Comparing the above described device with devices now ordinarily in use for the purpose of synchronizing, in regard to these criteria, we find:

(1) In regard to the first point, no difference obtains.

(2) In regard to the second point, the new device gives complete information, while ordinary devices give none.

(3) In regard to the third and most vital point, usual devices give only partial information, while that given by the new device is complete not only at the point of snychronism, but at every other point in the cycle."

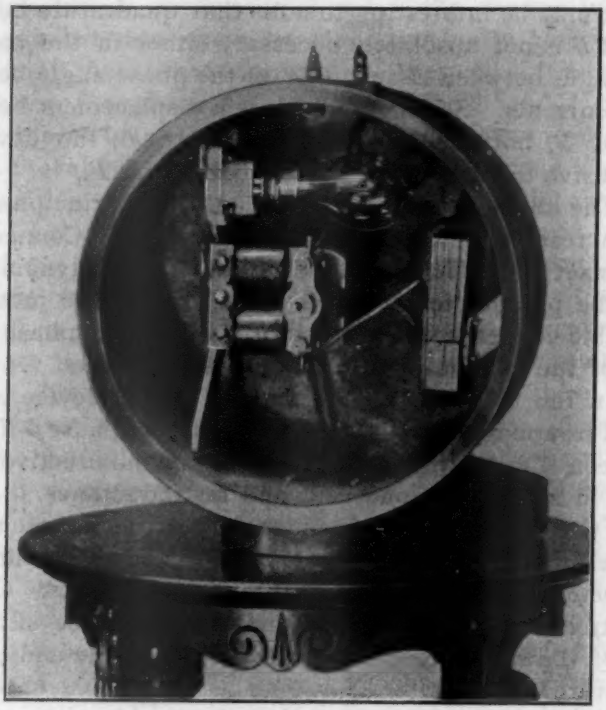

FIG. 2.

Fig. 2 shows a view of the synchronizer with dial removed. The lamp serves the double purpose of illuminating the translucent dial and of acting as the dead resistance in series with one of the armature elements. The inductive resistance in series with the other armature element is shown at the right. The field of the instrument, corresponding to coil *F* in the preceding description, is shown in the center. The armature is swung between its pole-pieces.

The experience with this device in connection with the alternators of the Niagara Falls Power Company has been most gratifying. The record performance has been the paralleling of five 5,000-horse-power dynamos in three minutes—a feat that under former conditions would have been quickly done in fifteen or twenty minutes.

The present tendency toward large unit and stiff regulation demands that the indication of synchronism for paralleling shall be done by something other than a makeshift, as has been largely the case in the past. Whether it be the device described above, or some other, the time has come when makeshifts should be discarded and a device better adapted to the purpose used for synchronism indication.

THE ENERGY OF THE UNIVERSE.

In a paper on the energy of the universe, in the *Revue Scientifique*, M. L. Skvortzow discusses the influence of electrical phenomena in cosmogony. He considers that in the past history of the earth, and of other celestial bodies, electrical and chemical energy have originally played the most important part, and that heat energy has become more and more important in proportion as the earth has assumed a more material form, so that the more its energy has passed from the dynamic to the static form the greater has been the absorption of dynamical energy in overcoming resistances. The heat of the earth M. Skvortzow attributes to electric currents circulating mostly near the surface; the interior of the earth, on the other hand, he thinks, may be as cold as the greatest depths of the ocean. Changes in the aspect of the earth, as well as meteorological phenomena, are attributed to electric currents induced by solar influence. The temperatures of different planets are considered to depend less on their distance from the sun than on their reserve of energy and on the currents which the sun induces in them in virtue of their axial and orbital motions. Will this theory of the electromagnetic origin of the earth's heat reconcile the two opposing views on the age of the earth? W.

INVENTION OF WIRELESS TELEGRAPHY.

According to a press cablegram, Marconi's claims to the invention of wireless telegraphy were severely criticised at a recent meeting of the French Academy of Sciences. According to documentary evidence adduced credit for the invention is due, first, to Feddersen and Maxwell, both Englishmen; then to Hertz, of Germany; but principally to Professor Branly, a Frenchman, who conceived and constructed in 1890 the receiver for electric waves which is used by Marconi; and next to Professsor Lodge, an Englishman, who read a paper before the Electrical Congress of 1894 pointing out the possibility of transmitting telegraphic signals with the Hertz apparatus and

receiving them with the Branly tube of metallic fillings, which possibility was actually put into practice by the Russian scientist, Popoff, in 1896. It was further asserted that most of Marconi's patents are worthless, owing to the foregoing facts. Finally, it was pointed out that neither the French nor the German Army nor the English Navy is using the Marconi system, though results are obtained equal to those obtained with his apparatus, except transmission across the ocean, which the scientists unanimously decided is yet unproved.—*Elec. World.*

NEW FRENCH PATENT REGULATIONS.

Hilary S. Brunot, Consul at St. Etienne, reports the following regarding the new patent regulation in France, which took effect early this year:

In order that a patent may be obtained in France, the three following conditions are necessary: That the invention be absolutely new; that it possesses an industrial character; that it be not contrary to public order or security, good morals, or the laws of the country. An invention is not considered new when, previous to the date of filing of the application, it has received sufficient publicity in France or abroad to render it easy of imitation.

The patents are not guaranteed by the Government, which delivers them at the risk and peril of the applicant; there may be noticed on thousands of patented inventions the letters "S. G. D. G.," meaning "without the guaranty of the Government."

The cost of a French patent is 500 francs ($96.50) for five years; 1,000 francs ($193) for ten years; and 1,500 francs ($289.50) for fifteen years. This tax is paid in annuities of 100 francs ($19.30) in advance.

To obtain a patent every inventor must file at the prefecture of his department.

"*a.* An application to the Minister of Commerce and Industry in which is mentioned the subject of his invention as well as the desired duration of the patent.

"*b.* A complete description of the invention in duplicate.

"*c.* Drawings or specimens necessary to the understanding of the description, also in duplicate.

"*d.* A list of the papers thus filed."

The decree above alluded to concerns exclusively the drawings and descriptions of the inventions. The first article prescribes that the descriptions must be written with the pen in a clear hand, or printed on paper 33 centimeters long by 21 broad (12¾ x 8 inches), leaving a margin of 4 centimeters (1½ inches). One side of the paper only must be used, and no design is allowed in the text. The second article refers to the drawings.

For the first six months of 1902 the decree will not be applied in an absolute manner.

The courts of Lyons have recently rendered a decision interesting to patentees. By the law of 1844 the person who has obtained a patent must work his invention in France within two years after the date of patent or he will lose his rights.

The courts have decided that the working must be real, and that publicity due to the cession of the patent to another party is not sufficient. W.

ELECTRICAL SECTION.

Stated Meeting, held Thursday, March 2, 1902.

ELECTROCHEMICAL POLARIZATION.

By C. J. Reed.

If the conceptions of different individuals are indicated by the definitions they give of a phenomenon, it must be admitted that there is not at the present time any very definite conception of electrochemical polarization.

Before discussing the phenomenon of polarization itself, it will be interesting to consider a few of the definitions given by various authorities.

Wetham defines it as "A peculiar condition of platinum plates." According to this definition it would not be difficult to avoid polarization in a galvanic battery, as it would only be necessary to avoid platinum plates.

Neuman defines it as "Increased resistance of the cell and consequent falling off of the current." According to this view, polarization could be avoided whether the plates be of platinum or not, by merely increasing the surface of the plates and reducing the distance between them.

McMillan says, "Polarization is hydrogen films on the surface of the negative strip."

Park Benjamin says, "Polarization is a condition due to the formation of a body, most commonly hydrogen, by electrochemical decomposition upon the negative electrode, whereby a current in opposite direction to the normal current of the cell is produced, and through which the normal current may be greatly weakened. To remove this body by any suitable means, chemical or mechanical, is termed 'depolarizing;' and if a chemical agent is employed for the purpose, it is called a 'depolarizer.'"

Neuberger says, "By polarization is meant any phenomenon, or the sum of all phenomena, which require an increase of voltage during electrolysis. These phenomena

are (*a*) deposition of gases at the electrodes whereby the gases cause an opposite current through the electrolyte; (*b*) the resistance of very dense layers of gas between poles and electrolyte; (*c*) changes of concentration in the electrolyte; (*d*) changes of temperature."

Grawinkel and Strecker define it as follows: "If the condition of the electrolyte or of the electrode is changed, an electromotive force is produced in the electrolytic cell at the electrodes, counteracting the external electromotive force and, therefore, diminishing the current. This phenomenon is called polarization, and the electromotive force produced in the cell is called the electromotive force of polarization or the counter-electromotive force.

The following is given by Prof. Houston: "The collection of a gas, generally hydrogen, on the surface of the negative element of a voltaic cell." "The collection of a positive substance like hydrogen on the negative element or plate of a voltaic cell sets up a counter-electromotive force, which tends to produce a current in the opposite direction to that produced by the cell.

"Polarization causes a decrease in the normal current of a cell:

"(1) On account of the increased resistance of the cell from the bubbles of gas which form part of its circuit.

"(2) On account of the counter-electromotive force produced by polarization.

"There are three ways in which the ill-effects of polarization of voltaic cell can be avoided.

"(1) *Mechanical.*—The negative plate is furnished with a roughened surface, which enables the bubbles of gas to escape from the points on such surface; or a stream of gas or air is blown through the liquid against the plate and thus mechanically brushes the bubbles off.

"(2) *Chemical.*—The surface of the negative is surrounded by some powerful oxidizing substance such as H_2CrO_4 or HNO_3, which is capable of oxidizing the hydrogen and thus thoroughly removing it from the plate.

"(3) *Electro-Chemical.*—The negative element is immersed in a solution of a salt of the same metal as that forming

the negative plate. Thus a copper plate in copper sulphate cannot be polarized, since metallic copper is deposited on its surface by the action of the hydrogen which tends to be liberated."

We see from these definitions that polarization is a condition, a substance, a resistance, an increase of resistance, an electromotive force, a counter-electromotive force, an obstructing body, a film of hydrogen, a gas, a collection of positive substances, bubbles of gas, the resistance of a dense layer of gas, a change of concentration, a change of temperature, a current opposing a normal current, the counteracting or diminishing of an external current, a decrease in a normal current, or the sum of all these things or phenomena.

Most authors discuss polarization without attempting to define it. This is fortunate. Otherwise we should probably be obliged to select our definition from a much larger assortment of material and immaterial than that given above.

It is evident that different persons have had different things or phenomena in view when they defined polarization. Some, for example, evidently have had the ammeter in view and noticed a diminution of electric current; others have had a voltmeter in view and noted a change in potential difference; others have had the negative electrode in view and saw bubbles of gas rising from it; while some have had a thermometer or hydrometer in view and noted a change of temperature or concentration. Some have evidently had in view a galvanic battery evolving electrical energy, while others had in view an electrochemical cell absorbing energy.

It is quite apparent that at least a part of the confusion manifested in the above definitions is due to mistaking coincidence for cause and to the fact that theoretical assumption has been more convenient than the ascertaining of facts.

It is plain, from the definitions quoted above, that polarization is a phenomenon and not a substance. It is also evidently a phenomenon accompanying some kind of

change in the condition of an electrochemical cell. An examination of the facts shows that this change of condition is invariably the result of a single cause. This cause is the passage of an electric current through the cell and not the formation of hydrogen or of any other substance. Polarization never occurs, except as a result of the passage of current, and there is no electrochemical cell in which the passage of a current does not tend to produce this changed condition, with which so many have struggled in attempts to frame a definition. The action of the current itself is always the cause of the changed condition, and the result of the passage of a current is always a change in the potential difference at the terminals of the electrochemical system during the passage of the current. This change in the potential difference is frequently in the direction opposed to the current flowing, but not always. The evolution of hydrogen and other substances at the cathode sometimes occurs simultaneously with polarization, but not always. Whether these substances are liberated or not depends altogether on the nature of the electrochemical reagents used, the speed of electrochemical reaction, the presence of reactions not electrochemical, the temperature and other conditions.

Faraday established the fact, and it has been verified many times since, that the passage of an electric current through an electrochemical cell is accompanied by electrochemical changes in the cell which are proportional to the quantity of electricity that passes. The inevitable effect of a current must be, therefore, to exhaust or destroy the chemical condition or composition of the cell as it was originally composed, and to produce a cell of different composition having different electromotive forces, resistances or concentrations. An apparent exception to this statement is found in the case of a cell in which the substances destroyed by electrochemical action at one electrode are produced at the other, and in which these substances are rapidly transported by some means from one electrode to the other. And it is only in such cases that there is apparently no polarization.

There is an intimate connection between the progressive electrochemical changes in a cell and its progressive polarization, which demonstratively points to the conclusion that polarization is most correctly defined as *a progressive change in the composition and electromotive force of an electrochemical system necessitated by the progressive exhaustion of one or more of the electrochemical reagents.*

All of the so-called phenomena of polarization are merely phenomena due to electrochemical exhaustion; that is, phenomena due to the change or substitution of a new electrochemical system for a preceding one.

To make this proposition clear by an illustration, certain electrochemical systems in action evolve hydrogen gas at the cathode; others do not. If the passage of an electric current through a system in which hydrogen is not evolved causes chemical changes which progressively convert the system into one evolving hydrogen, the ultimate result must be the evolution of hydrogen gas at the cathode.

In such a case the hydrogen should not be assumed to be the cause of polarization. It is the progressive polarization or exhaustion of the original electrochemical system which converts it into a new system, and one of the products of electrochemical change in this new system is hydrogen. In other words, it is polarization that causes the hydrogen, instead of hydrogen causing the polarization or being the polarization.

The evidence in support of these conclusions becomes manifest when we examine carefully the intimate relation existing between the energy evolved or absorbed in electrochemical reactions and the phenomena of polarization.

Electrochemical cells may be conveniently divided with reference to the energy of their electrochemical reactions into two classes—symmetrical and asymmetrical.

Symmetrical cells are those in which, when a current passes in either direction, the sum of the electrochemical reactions is zero and there is neither chemical nor electrical energy generated at the terminals of the cell by electrochemical action. Or, we may say, the quantity of electrical energy converted into chemical energy at one electrode is

equal to the quantity of chemical energy converted into electrical energy at the other electrode.

An aqueous solution, *Fig. 1*, of copper sulphate (of which the density is maintained in a uniform condition by rapid stirring) containing two copper electrodes, constitutes such a cell. The passage of a current in either direction causes copper to dissolve at the anode and an equal amount to be deposited at the cathode; the total amount of copper sulphate is the same in the final as in the initial state, or the sum of the electrochemical reactions is zero. The chemical energy of the copper dissolved at the anode is added to the energy of the circuit as electrical energy, and an equal amount of electrical energy is taken from the circuit at the cathode and converted into chemical energy by the deposition of the metallic copper. For cells of this class I have elsewhere

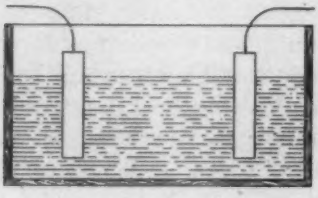

FIG. 1.

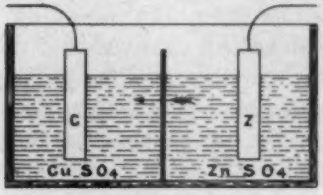

FIG. 2.

suggested the name of *agenic*, because neither electrical nor chemical energy is generated by conversion of one into the other between the terminals of the cell. Symmetry of structure or appearance does not constitute electrochemical symmetry. For instance, a solution of sulphuric acid containing two exactly similar platinum or carbon electrodes would not constitute a symmetrical cell. The passage of a current through such a cell, instead of producing at one electrode the substance consumed at the other, produces oxygen at one electrode and hydrogen at the other, and causes a continuous transformation of electrical into chemcal energy. A symmetrical electrochemical system must contain at the beginning a substance which is produced at one electrode and destroyed at the other by the electrochemical action.

An asymmetrical electrochemical system is one in which the passage of a current in one direction causes electrical energy to be converted into chemical energy, and the passage of a current in the opposite direction converts chemical energy into electrical.

A simple asymmetrical cell is shown in *Fig. 2*, in which *c* represents a copper electrode surrounded by copper sulphate, and *z*, a zinc electrode, surrounded by zinc sulphate, the two sulphates being separated by a porous partition. A current passing from *z* to *c* through the electrolyte dissolves the zinc at *z* and deposits copper at *c*. The dissolving of the zinc converts its chemical energy into electrical energy at *z*, and the deposition of copper converts electrical energy into chemical at *c*. But the formation energy of the zinc sulphate is greater than that of the copper sulphate. Hence, the electrical energy added to the circuit is greater than the chemical energy abstracted from it, and the cell generates electrical energy or is electrogenic. But as this action proceeds, the quantity of the copper sulphate is continually diminishing and will finally disappear altogether, while the quantity of zinc sulphate is continually increasing, and will eventually entirely replace the copper sulphate. As the current continues, the original asymmetrical system is progressively converted into a symmetrical system, and eventually zinc will be dissolved at *z* and deposited at *c*.

During the change in the composition of the cell; that is, during the exhaustion of copper sulphate, there is a simultaneous progressive change in the potential difference at the terminals of the cell. At the beginning, when the copper sulphate is abundant, there is an electromotive force of 1·09 volts and a potential difference of about 1 volt with a moderate current. But if the current be maintained constant, the potential difference will fall as the copper sulphate diminishes, and will become zero before copper sulphate is entirely exhausted. During this process the zinc sulphate gradually makes its way through the porous partition by diffusion, convection and molecular interchange and reaches *c*, replacing the copper sulphate.

It is this gradual reduction in the potential difference at

the terminals that constitutes the phenomena of polarization in this case, and it is evidently the necessary result of the change in chemical composition described. The substitution of the zinc sulphate for the copper sulphate is not, however, the only substitution that takes place. Water being always present in such a cell, and being more easily decomposed than zinc sulphate, begins to transmit a part of the current as soon as the copper sulphate is insufficient to transmit the current, and by its decomposition deposits hydrogen instead of copper. This continues to some extent even when there is sufficient zinc sulphate to transmit the total current.

If, however, a current be passed through the cell shown in *Fig. 2* in the opposite direction, viz., from *c* to *z* through the electrolytes, the copper will be dissolved at *c* and its chemical energy converted into electrical, at that point, while zinc will be deposited from solution at *z* and its chemical energy restored at the expense of electrical energy taken from the circuit at that point. As the formation energy of the zinc sulphate is greater than that of the copper sulphate, more electrical energy will be taken from the circuit at *z* in depositing the zinc than that which is added to the circuit at *c* by the dissolving of the copper. Hence, there will be a counter-electromotive force between the terminals of the cell opposed to the current. If a constant current be maintained through the cell in this direction, this counter-electromotive force will be 1·09 volts and the potential difference between the terminals will exceed this value so long as zinc sulphate is the only substance decomposed at *z*. But when some of the copper sulphate by diffusion, convection, molecular exchange or otherwise, arrives at *z*, it will be decomposed in preference to the zinc sulphate, as this requires less energy than the zinc sulphate for its decomposition. Only a small quantity of copper sulphate reaches *z* at first, which is sufficient to transmit only a small fraction of the total current, the balance still finding its way out of the electrolyte through the decomposition of the zinc sulphate. Consequently, the counter-electromotive force and the potential difference are

resultants of that due to the copper and that due to the zinc. This resultant potential difference and electromotive force must be less than that due to the zinc and greater than that due to the copper, its value varying with the relative quantities of current transmitted by the copper sulphate and by the zinc sulphate. Hence, when copper sulphate first reaches *z*, that is, when the system first begins to change from an asymmetrical to a symmetrical system, polarization sets in and the counter-electromotive force and potential difference begin to fall. As the copper sulphate increases and the zinc diminishes at *z* until the copper sulphate is in sufficient quantity to transmit the total current, the counter-electromotive force diminishes *pari passu* to zero and the potential difference nearly to zero. The cell has now been entirely changed from an asymmetrical to a symmetrical system by the substitution of the copper sulphate for the zinc sulphate, or by the total exhaustion of the zinc sulphate as the electrolytic medium of transmission for the current. The fact that some zinc sulphate still remains as an inert body in solution does not alter the case, but merely proves or illustrates the fact that when the zinc sulphate and the copper sulphate are equally accessible to the cathode in quantities sufficient to transmit the total current, the compound requiring the least absorption of electrical energy will be decomposed to the total exclusion of the one requiring greater energy.

This selective tendency of a current to be transmitted by a compound requiring the minimum absorption or maximum evolution of electrical energy in preference to other equally accessible compounds, has already been described before this Institute as the *law of maximum electrogenesis.** The recognition of this law makes it evident in a convincing manner that in every case the phenomena of polarization are merely phenomena of electrochemical exhaustion as described above.

Returning to the cell shown in *Fig. 2*, considered in its initial state, when the current passes with the arrow from

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* *Jour. Frank. Inst.*, May, 1901.

z to *c*, the system is evolving electrical and exhausting chemical energy. It is a galvanic battery in the process o discharging and furnishing electrical energy. Its polarization; that is, the exhaustion of the copper sulphate, causes it to become less and less efficient as a battery. Its electromotive force falls in time nearly to zero. But if the current be maintained by an external source after the copper sulphate has been exhausted, water will then be decomposed and hydrogen will be deposited instead of copper, and zinc oxide will be formed at *z* instead of zinc sulphate. This will commence when the potential difference falls to .34 volt.

Finally zinc and hydrogen are both deposited and the cell ceases to act as a battery, both electrodes being now of zinc. But if the original current is from *c* to *z* instead of from *z* to *c*, the system absorbs electrical and accumulates chemical energy. It is an accumulator in process of charging and continues to act as such until the copper sulphate reaches *z*. It then becomes less and less efficient as an accumulator, until its polarization, that is the exhaustion of its zinc sulphate, changes it completely to a symmetrical system, dissolving copper at one electrode and depositing it at the other. It now ceases altogether to act as an accumulator, ceases to convert electrical into chemical energy. In other words, it becomes an agenic cell, identical with that shown in Fig. 1, when the concentrations are the same.

In the brief time allotted we have been able to consider in detail only a single case, but the same process of investigation may be applied to all electrochemical systems without exception, and in every case the conclusion is the same, viz., that polarization is merely the progressive change described above.

—A CURIOUS ACCIDENT occurred in Boston a few days ago, resulting, it is stated, in considerable damage to the electrical equipment of the Boston Elevated Railway. A woman, evidently on a shopping tour, was carrying home two brass curtain rods, one of which dropped on the track at the Sullivan Square Terminal. It fell across the third rail and one of the traction rails, and short circuited the system. Considerable insulation was destroyed and traffic was interrupted for some time.

PHYSICAL SECTION.

Stated Meeting, held February 27, 1901.

ON THE HARMONIC CURVES KNOWN AS LISSAJOUS FIGURES.

BY HORACE C. RICHARDS.

Of all types of finite motion the simplest, as well as the most interesting, is that known as simple harmonic motion; the projection of uniform circular motion on a line in its plane. It is simpler than circular motion, for it is a component of that motion, and is confined to a straight line. It is simpler even than uniform rectilinear motion, for its reversal of direction involves no discontinuity of velocity. And to its simplicity is added an æsthetic charm. Alike in observing the reciprocating motions of an engine, the oscillations of a pendulum, and the majestic sweep of the tides, we feel a distinct sense of pleasure in the appreciation of this graceful rhythm.

It is, moreover, a type of motion most important from the physical point of view. Its chief property may be stated in the law that the acceleration is always directed toward the center of the motion and is proportional to the distance from that center. But this is the law of the motion of bodies under the action of an elastic force; and consequently we have to deal with this form of motion not only in those slow oscillations of elastic bodies which may be followed by the eye, but also in the more rapid vibrations met with in acoustical phenomena. The electrical waves emitted by an alternating dynamo and the vastly more minute electromagnetic waves which constitute light furnish other physical examples of the harmonic law.

It is on account of this importance of harmonic motion in physics that so much significance is attached to the law known as Fourier's theorem: that any periodic motion may be resolved into harmonic constituents. From the purely

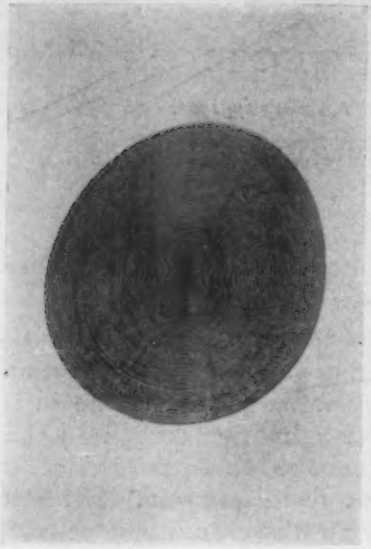

FIG. 1.

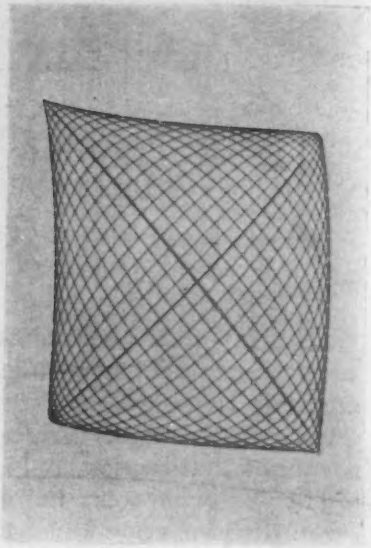

FIG. 2.

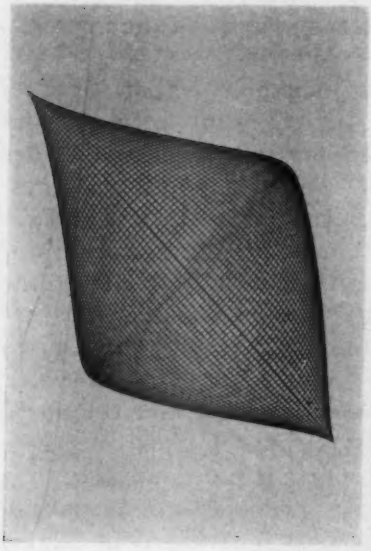

FIG. 3.

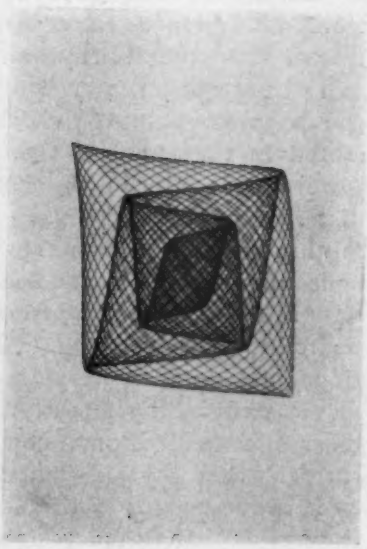

FIG. 4.

PLATE I.

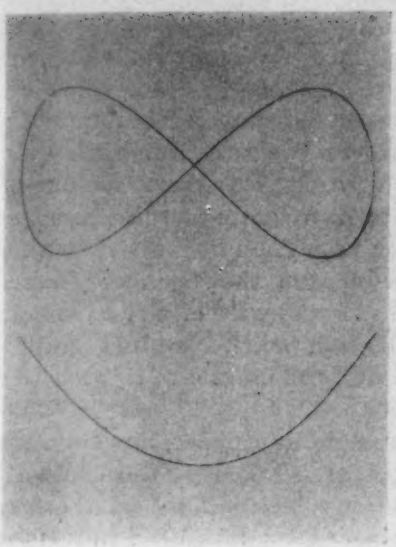

FIG. 5.

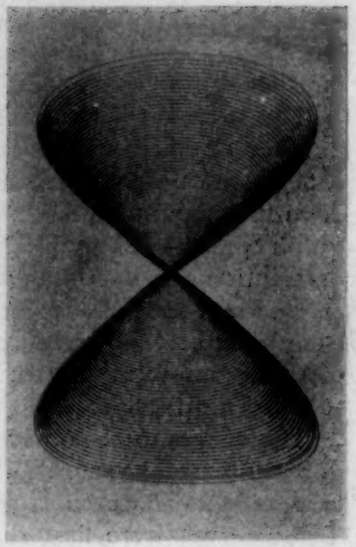

FIG. 6.

FIG. 7.

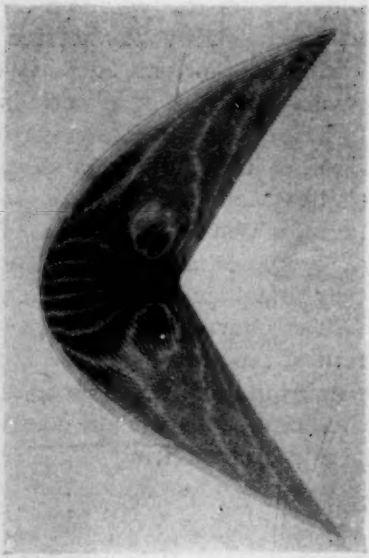

FIG. 8.

PLATE II.

mathematical point of view, other resolutions are possible; but they do not correspond to physically independent motions.

The converse of Fourier's problem—the combination of a number of harmonic motions in the same line—has been experimentally exhibited in the tide-predicting machine of Lord Kelvin, and much more completely in the harmonograph constructed by Michelson. The latter instrument, a description of which may be found in the *American Journal of Science* for 1898,* combines as many as eighty harmonic constituents; the resultant motion being exhibited graphically by combining it with a uniform motion at right angles to its own direction.

The curves to be considered in this paper, however, are of a different character. They are formed by the composition of two harmonic motions inclined to each other. These curves were first discussed by Bowditch in 1815 †, but as they were first brought into prominence forty years later by the beautiful acoustical experiments of Lissajous, they are generally known as Lissajous figures. They may be produced by any device capable of compounding two harmonic motions, such as a pendulum swinging in two planes with different periods (Dean, Blackburn), a beam of light reflected successively from two tuning-forks (Lissajous), a rod of rectangular or elliptic section vibrating laterally (Wheatstone), or a tracing-point governed by two pendulums which oscillate in planes inclined to each other (Tisley). It is by the last process that the curves illustrating this paper were drawn.

The character of the curve depends mainly on the relation of the periods of the components. Some general properties may however be deduced. Representing by a and b the amplitudes of the component motions, T_1 and T_2 their periods, and writing

$$\omega_1 = \frac{2\pi}{T_1}, \quad \omega_2 = \frac{2\pi}{T_2},$$

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* *Am. Jour. Sci.* (4) **5** p. 1 (1898). Also *Phil. Mag.* (5) **45** p. 85 (1898).
† Mem. Acad. Arts and Sci. [1] **3**, pp. 241, 413 (1815).

the curve in general may be represented by

$$\text{I.} \qquad \begin{cases} x = a \cos \omega_1 t, \\ y = b \cos (\omega_2 t - e), \end{cases}$$

e being the possible difference of phase. It is evident that the curve is always contained in the parallelogram $x = \pm a$, $y = \pm b$. If, as is usual, we take rectangular axes, the inclosing parallelogram becomes a rectangle.

If T_1 and T_2 are incommensurable, x and y will never simultaneously return to their original phases, so the curve will have no period. Otherwise, if the ratio of the periods, reduced to its lowest terms, be $n : m$, the initial phases will first recur together after a time

$$T = m\, T_1 = n\, T_2.$$

The curve will therefore have a period which is the least common multiple of the component periods. In this case, which is the most interesting, we may write equations I

$$\text{II.} \qquad \begin{cases} x = a \cos m\, \omega\, t, \\ y = b \cos (n\, \omega\, t - e), \end{cases}$$

where

$$\omega = \frac{2\pi}{T}.$$

From these equations we see that in each period x and y take their maximum values m and n times respectively. In other words, the curve will have m loops along the sides $x = \pm a$ and n loops along the sides $y = \pm b$ of the parallelogram. This property furnishes a ready means of determining the ratio of the components from an inspection of the curve. It must be noticed, however, that in certain special cases, where the curve retraces itself backward in the second half of its period, each loop must be counted twice and each free end as a single loop. Examples of this may be noted in *Figs. 5, 9, 13*, etc.

The curves possess some general properties of symmetry which may be readily deduced. Since the ratio $n : m$ is in its lowest terms, we may without loss of generality take m always odd. Consider the position of the tracing point one half period after the time t. We find this by substituting for t in equations II

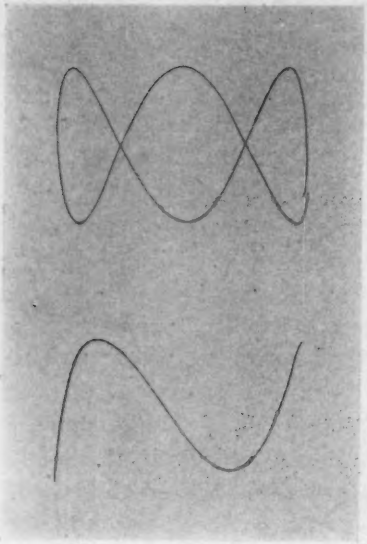

FIG. 9.

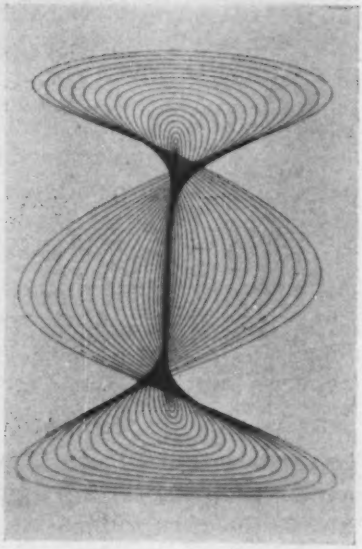

FIG. 10.

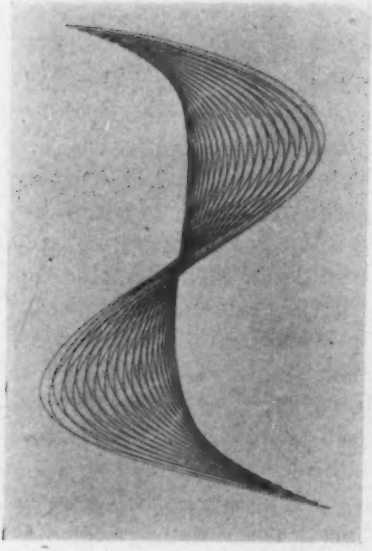

FIG. 11.

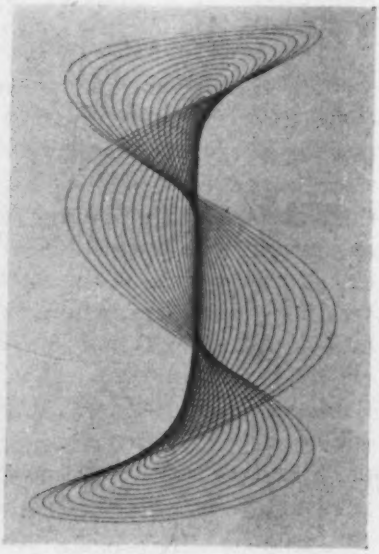

FIG. 12.

PLATE III.

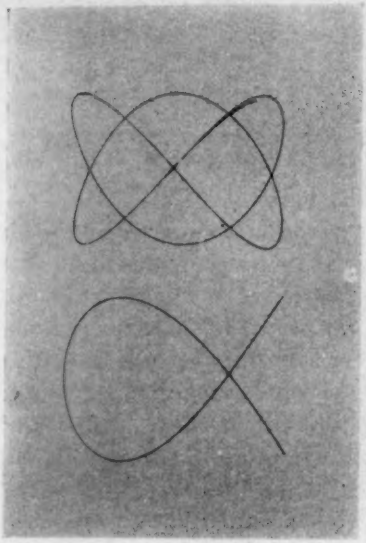

FIG. 13.

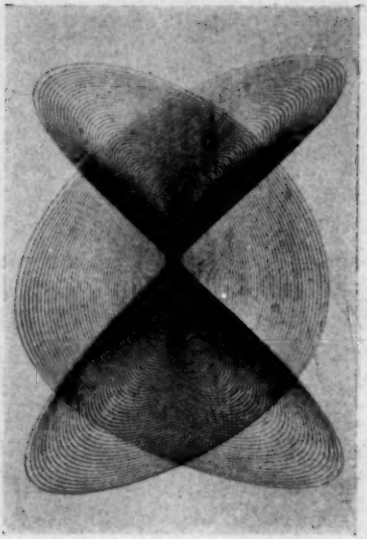

FIG. 14.

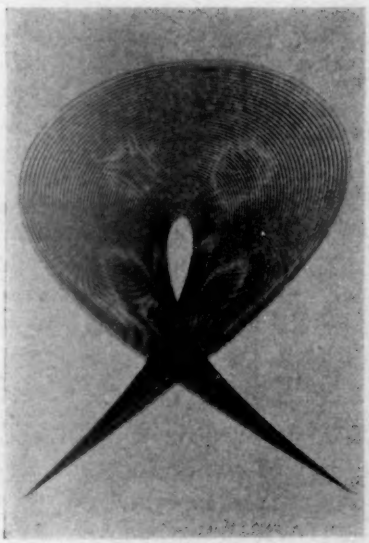

FIG. 15.

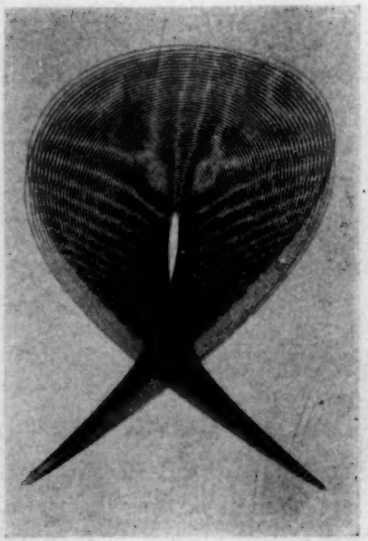

FIG. 16.

PLATE IV.

$$t' = t + \frac{1}{2}T = t + \frac{\pi}{\omega}$$

which gives

$$x' = a \cos(m\,\omega\,t + m\,\pi) = a \cos m\,\omega\,t \cos m\,\pi,$$

$$y' = b \cos(n\,\omega\,t - e + n\,\pi) = b \cos(n\,\omega\,t - e) \cos n\pi.$$

Now as m is odd, x' always equals $-x$; while y' is equal to $+y$ or $-y$, according as n is even or odd. We may therefore distinguish two classes of curves: (1) If n is even, corresponding to every point (x, y), there is a point $(-x, y)$, traced half a period later; in other words, the curve is symmetrical about the axis of y (the *even* axis). (2) If n is odd, corresponding to each point (x, y), there is a point $(-x, -y)$, or the curve is symmetrical about its center, but not in general about either axis.

Cases of especial interest occur when e takes the values 0 and $\frac{\pi}{2}$. These cases are known as the end phase and middle phase of the curve. (If e equals π or $\frac{3\pi}{2}$ we have merely a reversal of these curves.)

(1) *End Phase:* $e = 0$. Equations II become

III.
$$\begin{cases} x = a \cos m\,\omega\,t, \\ y = b \cos n\,\omega\,t. \end{cases}$$

Consider now the position of the tracing point at a time t before the end of the period. This we find by substituting for t in equations III,

$$t'' = T - t = \frac{2\pi}{\omega} - t;$$

which gives

$$x'' = a \cos(2\,\pi\,m - m\,\omega\,t) = a \cos m\,\omega\,t = x.$$

$$y'' = b \cos(2\,\pi\,n - n\,\omega\,t) = b \cos n\,\omega\,t = y.$$

It follows that in the second half of the period the curve retraces backward the path described in the first half. It is no longer closed but has free ends, which are at adjacent or opposite corners of the rectangle according as n is even or odd. It has no higher symmetry than in the general case.

(2) *Middle Phase:* $e = \frac{\pi}{2}$. Equations II become

$$\text{IV.} \qquad \begin{cases} x = a \cos m \omega t, \\ y = b \sin n \omega t. \end{cases}$$

Making the same substitution for t of $T - t$, we obtain

$$x'' = a \cos (2 \pi m - m \omega t) = a \cos m \omega t = x.$$

$$y'' = b \sin (2 \pi n - n \omega t) = - b \sin n \omega t = - y.$$

The curve is symmetrical about the axis of x. But we have seen that in general, if n is even the curve is symmetrical about the axis of y, while if n is odd it is symmetrical about the center. In all cases, therefore, the curve in its middle phase is symmetrical about both axes.

The curves corresponding to the two simplest ratios may easily be investigated more closely. If $m = 1$ and $n = 1$ we have the figure corresponding to unison. Equations II become

$$\text{V.} \qquad \begin{cases} x = a \cos \omega t, \\ y = b \cos (\omega t - e). \end{cases}$$

Eliminating ωt we obtain the equation of the path

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - 2 \frac{x y}{a b} \cos e = \sin^2 e,$$

which represents an ellipse. At the end phase it reduces to a straight line

$$\frac{x}{a} = \frac{y}{b},$$

while at the middle phase it becomes the symmetrical ellipse

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1.$$

The next ratio, that of the octave ($m = 1$, $n = 2$), is expressed by the equations

$$\text{VI.} \qquad \begin{cases} x = a \cos \omega t, \\ y = b \cos (2 \omega t - e), \end{cases}$$

and eliminating ωt as before, we obtain the equation of the path

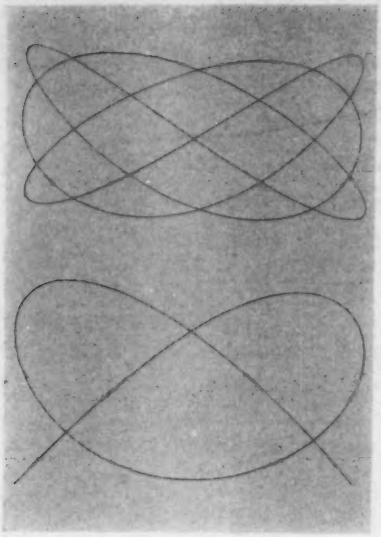

FIG. 17.

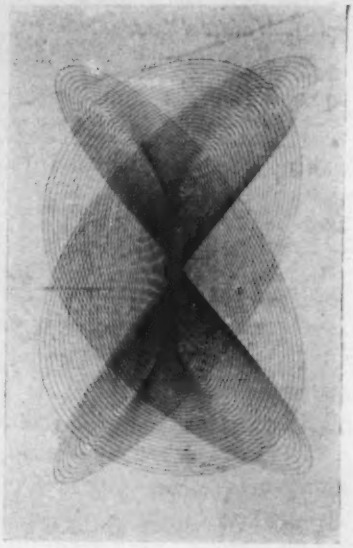

FIG. 18.

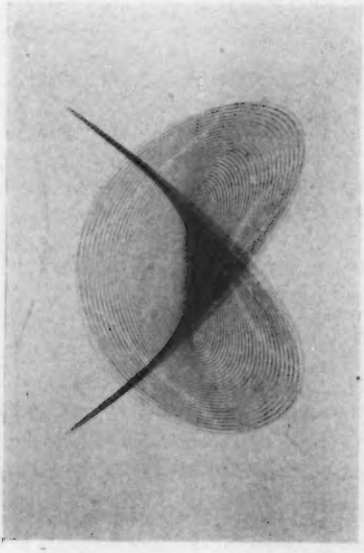

FIG. 19.

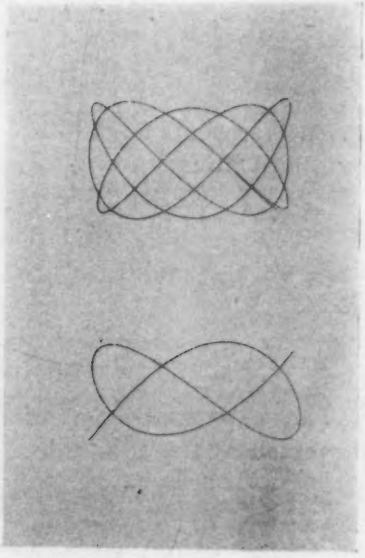

FIG. 20.

PLATE V.

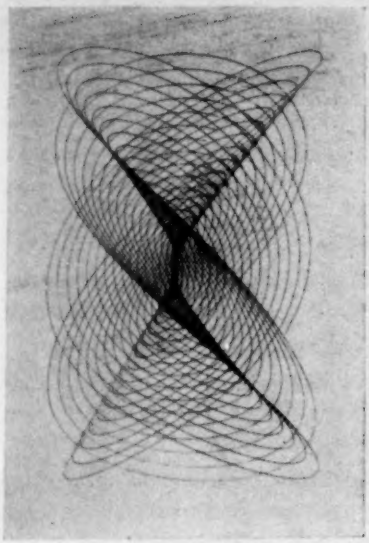

FIG. 21.

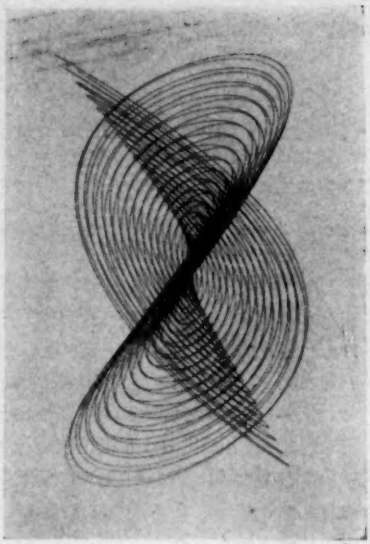

FIG. 22.

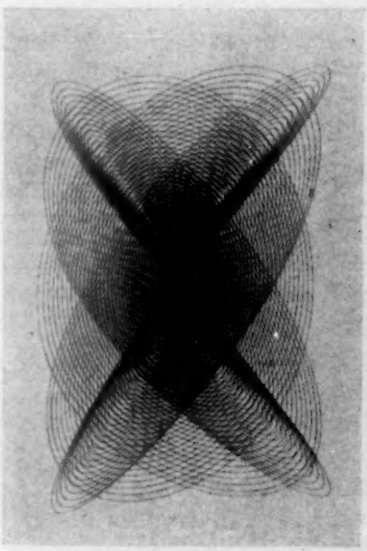

FIG. 23.

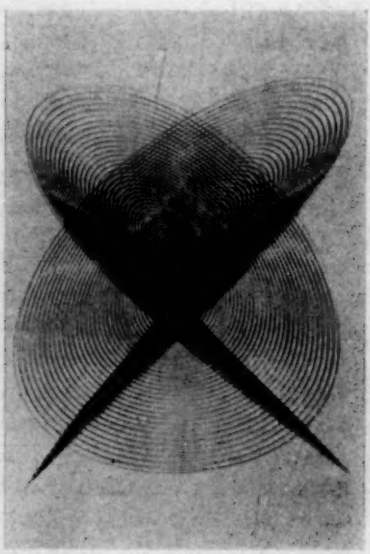

FIG. 24.

PLATE VI.

$$\frac{y}{b} = \left(2\frac{x^2}{a^2} - 1\right)\cos e + \left(2\frac{x}{a}\sqrt{1 - \frac{x^2}{a^2}}\right)\sin e$$

The general curve is of the fourth degree At the end phase it reduces to the parabola

$$\frac{y}{b} = 2\frac{x^2}{a^2} - 1,$$

and at the middle phase it becomes

$$\frac{y^2}{b^2} = 4\frac{x^2}{a^2}\left(1 - \frac{x^2}{a^2}\right),$$

a curve similar to the lemniscate and known as the hippopede. (See *Fig. 5*, Plate II). Curves corresponding to less simple ratios are much more complex and do not lend themselves readily to detailed analysis.

So far we have considered commensurable ratios. When the ratio is incommensurable, the curve, as before stated, is not periodic.

A case of interest occurs when the ratio of the periods is nearly that of two small integers. Writing this ratio $(n + a) : m$, where m and n are integers and a is a small fraction, and retaining the relation $\omega_1 = m\,\omega$, equations I may be written

VII.
$$\begin{cases} x = a\cos m\,\omega\,t, \\ y = b\cos(n\,\omega\,t + a\,\omega\,t - e). \end{cases}$$

These correspond to equations II, except that the phase e is replaced by a phase varying with the time,

$$e' = e - a\,\omega\,t.$$

If a is so small that there is no appreciable change in this phase during the time $2\pi \div \omega$, the curve traced in that time will correspond to the ratio $n : m$; but as it is repeated the phase slowly changes, so that the various forms of the $n : m$ curve are successively traced. It may, therefore, be described briefly as an $n : m$ curve of variable phase. This type of curve is beautifully illustrated in Lissajous' experiment with two tuning-forks when the interval is not exact.

The curves illustrating this paper were drawn with the instrument known as the Tisley compound pendulum or harmonograph. It consists essentially of two heavy pen-

dulums of adjustable period mounted so as to oscillate in perpendicular planes. A horizontal arm attached to the upper part of each pendulum and extending in the direction of vibration communicates its motion to a tracing point hinged at the intersection of these arms. When both pendulums are swinging, the point will receive a harmonic displacement from each pendulum, and the resultant curve will be of the character we have discussed. As the component motions are not perfectly independent nor strictly harmonic, there is a slight distortion in the curve, which is especially noticeable when the amplitude is large. The curve may be traced on paper by using a glass tube drawn to a capillary tip and filled with ink, or it may be traced on smoked glass with a needle-point.

If the tracing is allowed to continue after the end of a period, the curve will of course be repeated, but, on account of the loss of amplitude due to friction, the successive curves will be traced within one another, forming the graceful figures characteristic of the Tisley pendulum. Unless great care is taken to have the periods of the pendulums accurately commensurable, the gradual change of phase will alter the form of the curve, and often diminish the symmetry and consequent beauty of the resulting figure. If the components are "in tune," however, a slight deviation of the phase from zero will cause the lines to cross at a small angle and so produce the watered effect which enhances the beauty of the curves. A very slight change of phase will entirely alter the appearance of the watering. Examples of this may be seen in Plates II and IV.

The original curves, of which those on Plates I to VI are reversed copies,* were traced on smoked glass. The glass was first wiped with an oiled cloth so that the needle-point should sweep smoothly over the surface without chattering.

* In the reproduction some of the fine detail is lost. The originals, of course, consist of fine sharp lines. In a few of the reproductions there is an additional effect of watering not on the originals, due to the interference between the lines of the figures and those of the process screens. This is most marked in *Fig. 1*, which in the original shows no trace of watering, being simply a long spiral.

It was then coated as evenly as possible with a film of soot from a small flame of burning camphor, the film being just thick enough to be opaque. It is important that the soot be of fine texture and not too coherent, otherwise it will be detached from the glass in flakes. Camphor smoke was found to be much more satisfactory than the smoke from gas or oil. The needle used was stout, so as not to bend, and had to be frequently sharpened to give the finest lines. The periods of the pendulums were adjusted first with heavy fixed weights, then with a smaller sliding weight on one, till the desired ratio was accurately secured.

Plate I illustrates the ratio 1 : 1 or *unison*. *Fig. 1* gives the middle phase, the tuning being practically perfect. The resulting curve is therefore a long spiral. *Fig. 2* illustrates a slight deviation from unison, the sliding weight being purposely displaced. The curve starts in the end phase (a diagonal line) but changes to a variable ellipse which opens out and then closes up to the opposite diagonal corresponding to $\epsilon = \pi$. In this curve the ratio is about 39 : 40. In *Fig. 3* the deviation from unison is less, and the change of phase is therefore slower. In these two curves the tracing point was lifted after half a cycle. *Fig. 4* exhibits the result of allowing it to continue through two cycles. These figures belong to the second class, as they are not in general symmetrical about either axis.

Plate II illustrates the *octave*, 2 : 1. These belong to the first class and are always symmetrical about one axis. *Fig. 5* gives the typical curves of the principal phases—the hippopede and the parabola. *Fig. 6* shows the middle phase, and *Figs 7* and *8* the end phase. These last exhibit the effect of watering, the phase not being exactly zero.

Plate III illustrates the *twelfth*, 3 : 1. These belong to the second class. *Fig. 9* gives the typical curves, *Figs. 10* and *11* the principal phases, and *Fig. 12* an intermediate phase.

Plate IV illustrates the *fifth*, 3 : 2. *Figs. 15* and *16* exhibit varieties of watering. In *Fig. 15* the phase is very nearly zero, so the watering is slight, while in *Fig. 16* there is a distinct difference of phase, and the watering is very marked.

Plates V and VI illustrate the ratios 4 : 3, 5 : 3 and 5 : 4, or the intervals of the *fourth*, *sixth* and *major third*. These show the same general characteristics. As the ratio becomes expressible by larger numbers the curves begin to lose their individuality; for example, the middle phase of 4 : 3 and 5 : 4 (*Figs. 18* and *23*) resemble each other closely.

The series of figures of the end phases also are related. For instance, comparing *Fig. 7* with *Figs. 15, 19, 22, 24*, we may regard the latter figures as produced from the first by bending it more and more as the ratio becomes more complex. Of course, we may consider *Fig. 7* itself as produced by the bending into parabolas of the diagonal line forming the end phase of the ratio 1 : 1, repeatedly traced with diminishing amplitude.

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A NEW IRON PIGMENT.

A new pigment is thus described by the *Electrical World and Engineer*: Dr. Alexander S. Ramage, of Cleveland, O., discloses a method of producing a remarkable iron pigment, with an old formula and new properties—the hydrated basic ferric oxide $Fe_2O_3Fe_2(OH)_6$. It presents one of the first commercial applications of those physico-chemical theories which have been developed largely by the study of dilute electrolytes. In outline the process is as follows: The waste ferrous liquor derived from iron pickling—generally ferrous sulphate or chloride with some free acid—is neutralized and then oxidized by the joint action of air and steam. As the oxidation proceeds an alkali, as sodium carbonate in solution, is added in quantity sufficient to maintain substantial neutrality, and simultaneously therewith a large volume of water, which, as will appear, is the true precipitating agent.

The effect is that known as hydrolysis, or the decomposition by water of a salt composed of a base and acid between which there is a great disparity of strength, in the present instance a compound of a weak base with a strong acid. By the oxidation of ferrous sulphate, basic ferric sulphate is formed, and this salt in the presence of the large volume of water is hydrolyzed, yielding sulphuric acid and basic ferric hydrate—the pigment in question. A reaction of this character would, of course, soon reach an equilibrium and the yield of pigment would be but small, wherefore the gradual addition of the alkali to combine with the acid as it is liberated and to insure the continuance of the reaction to complete precipitation of the iron. The pigment is light yellow in color, but is readily converted by heat into the several iron oxide reds, and affords also a suitable base for mixed pigments. Its absorptive capacity for oil greatly exceeds that of the standard pigments, being two and

one-half times that of standard French ocher, and seven and one-half times that of white lead. Its covering power, as compared with these pigments, is almost proportionately high.

TEXAS FUEL OIL TESTS.

A Texas oil company has printed a report of Prof. J. E. Denton, of Stevens Institute, upon tests at Beaumont, Texas, of crude petroleum as fuel, made for the company. The tests were made in a horizontal return tubular boiler 6 feet in diameter, 18 feet long, and having a grate surface of 45 5 square feet. In the tests, data for comparative purposes were obtained from the same boiler when burning buckwheat anthracite coal. With Beaumont crude oil the equivalent evaporation from and at 212° was 15·49 pounds of water per pound of oil. The corresponding figure when using buckwheat coal was 11·79 pounds of water per pound of combustible, and 8·94 per pound of coal. The efficiency of the boiler determined by the oil tests was 78·5 per cent. and by the coal tests 77·6 per cent. A quantity of steam varying from 3·1 to 4·8 per cent. was consumed in the oil blast. In the two tests with coal the horse-power developed by the boiler was 92·6 and 119·1 In the five tests with oil the horse-power varied from 112·7 to 220·1 horse-power, the evaporation per pound of oil from and at 212° in the first mentioned case being 15·05 and in the second 14·75. These figures are considerably less than those that have been obtained with Eastern crude petroleum, which range above 18 pounds of water per pound of oil.—*Electrical World.*

SUBTERRANEAN TEMPERATURE.

The driving of the great Simplon tunnel through the Alps is affording some interesting data on the subject of subterranean temperature. The work has progressed in the north heading over 21,000 feet, and in the south heading over 17,000 feet. Temperature observations have been taken both of the rock and the atmosphere. The temperatures of the rock show a steady increase with the depth of penetration in both headings. Thus at 1,640 feet from the portal of the north heading the rock showed a temperature of 54·3° F., while in the south heading at the same distance from the portal the temperature was 56·2°. At 6,560 feet the temperature in the north heading was 63·6°, and in the south heading 69·7°. At 12,920 feet from the north heading the temperature was 76·3° ; at 15,090 feet it had risen to 86·3°, and at 16,400 feet penetration the temperature of the rock was 89·1°. The highest temperature recorded previous to September last was 92·2° F. Early in October a heavy stream of water was encountered, which temporarily drove the gangs of workmen from the heading and necessitated temporary suspension of work in the main tunnel. The heaviest flow of water recorded at that time was about 200 gallons per second ; and while it has been productive of considerable inconvenience in the tunnel work, it brought with it the advantage that it produced a very marked decrease in the temperature of the rock. The temperatures of the air are not given, for the reason that they vary with the amount of ventilation. During the summer it was found necessary to deliver to the northern end of the tunnel 39,000 cubic feet of air, and 66,000 cubic feet to the south end.—*Scientific American.*

PHYSICAL SECTION

Stated Meeting, held Tuesday, December 17, 1901.

THE MECHANISM AND CAUSATION OF HOT WAVES.

BY HARVEY M. WATTS.

In looking into the question of their causation it must be clearly understood, to begin with, that hot waves in the United States, Europe and Australia are due exactly to the same general conditions. The hot wave is the resultant of a certain definite trend in the general circulation of the atmosphere, and is not "local" in origin in any sense, localities, according to their situation and topography, merely modifying or intensifying the general conditions favorable to the production and continuation of high temperatures.

While, therefore, the hot waves in the United States are not caused by the "deforestation due to advancing civilization," as has been suggested in a British medical periodical, it is true that the lay of the land in certain parts of the United States does favor the intensification of hot waves after they have been set up by general causes, cosmical in origin and terrestrial in sweep and extent. In brief, the meteorological mechanism of hot waves, which is very simple, is as follows: The initial cause is a certain stress in the shape of a high pressure (barometric) area in the general circulation which sets up a movement of air from the south, from the tropics northward; secondly, this stress, which is far-reaching and reacts all around the globe, slows up the normal eastward drift of the serial eddies in the North Temperate Zone, and produces a stagnation in the lower atmospheric levels; thirdly, the local circulation thus set up causes certain changes in the upper levels of the lowermost stratum of the atmosphere in the matter of moisture content, so that radiation at night is checked and the air retains the heat gained during the day in abnormal

measures; and, lastly, what with the south-to-north circulation, clear, pitiless skies during the day and the checking of radiation at night, vast areas of land favorably situated become overheated until an enormous extent of territory is covered with a blanket of superheated air, which extends to a considerable height, and, indeed, carries the temperatures up to the higher cloud level. The duration or extent of the hot waves thus established is unaffected by the local conditions, however, and the hot wave can only give way through a change in the drift of the air, a reversal of the south-to-north system of circulation, This reversal can only come through an about-face in the mechanism of the general circulation, and is neither affected by bombardment of dynamite nor by prayers. any more than the law of gravitation would be changed by similar human efforts.

The hot wave, therefore, plays its part in connection with what are known as the fixed or permanent characteristics of the general circulation of the globe. These fixed relations take the form of a belt of high pressures near the tropics and a belt of low pressures near or at the poles. In between these two permanent systems move, in a great eastward swirl, the enormous aerial eddies that condition weather and climate in the North Temperate Zone. These eddies are only two, the high-pressure, anticyclonic, down-draught eddy (called "highs" for short) and the low-pressure, cyclonic, up-draught eddy (called "lows" for short). The highs are the center of clear weather phenomena, the lows the center of stormy, cloudy weather. While they ever move eastward, their rate of motion and the location of their paths are determined by the general movements of the atmosphere, and it is these variations that produce the marked seasonal vagaries, cold or mild winters, moderate or tropical summers, as the case may be. Whenever, for instance, the general circulation brings it about that the subtropical high pressures tend to increase in area and intensity, this means a summer of hot waves, for this has the effect of retarding the eastward drift and of holding up the migratory areas of high pressure, so that the air circulates sluggishly from the South, from the tropics poleward,

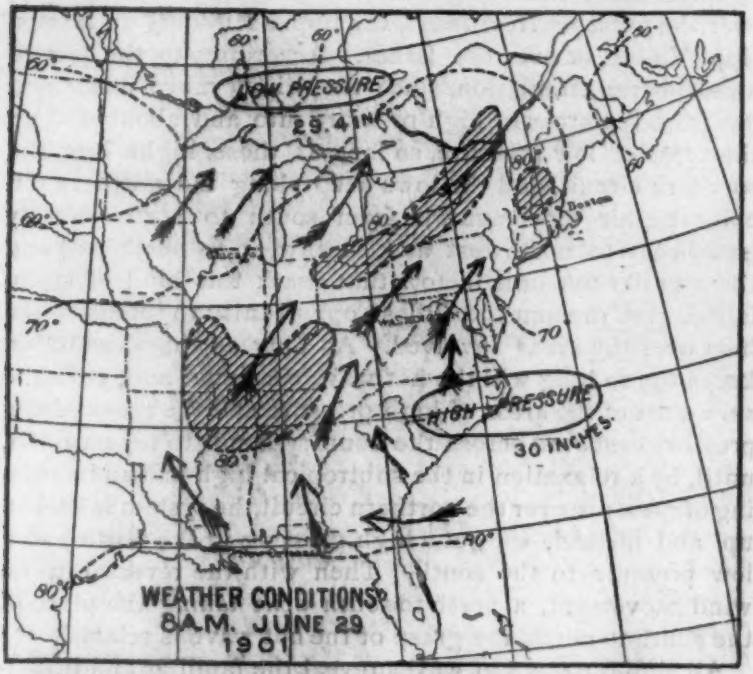
and, being relatively and at times dynamically warm, what with the effect of 100 per cent. of sunshine daily, makes possible the terribly heated periods with their maxima of over 100°.

As specifically revealed on the United States Weather Bureau maps, our hot waves set in when there is a high over Texas, the Gulf, the Southern States or over the Bay of Charleston, extending out toward Bermuda, with a low over the extreme Northwest, the upper Missouri or Mississippi Valley, or over the Lakes. According to the law of atmospheric circulation, since the winds move down and out from the areas of high pressure into and about and up the areas of low pressure, so long as these highs hug the southern circuit, and the lows keep along the northern circuit, the air movement, if from south to north spirally (southeast to northwest and southwest to northeast) and the peculiar dynamic factors that mark this kind of circulation, give the sun the fullest opportunity to intensify the heat over the areas involved. As long as this circulation keeps up, so long will the hot wave continue; and, with the slow shift of the areas of high pressure and the areas of low pressure eastward across the country, tends to repeat itself, until, by a relaxation in the subtropical high and an increasing of pressure over the northern circuit,the system is broken up, and instead, we get a high pressure in the north and a low pressure to the south. Then with the reversal in the wind movement, a north-to-south drift taking the place of the south-to-north, the grasp of the hot wave is relaxed.

All our famous hot waves reveal the familiar and invariable mechanism described. The great hot wave of August 3-18, 1896, which wrought such a terrible loss of life in New York and other large cities, and broke all records of deaths until surpassed by the record of the hot wave of June 26-July 7, 1901, was due to a persistent area of high pressure over the Southern States, which discharged its dynamically heated tropical air into the areas of low barometer, which, while slowly moving eastward, kept persistently in the North.

Coming to the extended hot wave of June-July-August, 1901, the daily weather maps reveal the same circulation--high

pressure over the Gulf States and lows over the west, northwest and Lake Region. So long as this kept up the rigors of the heat were unabated, but the break that came to the Middle Coastal States, the upper Lake Region, New England and certain portions of the Central States during the week of July 8th to 15th was due to a deepening of pressure over the Lakes and New England and the appearance of a



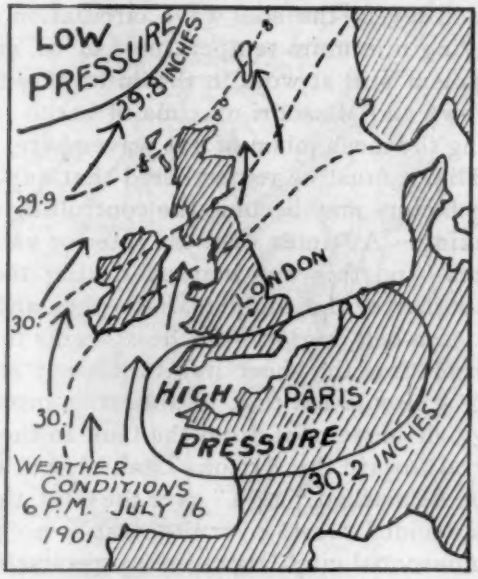
Hot-weather conditions over the eastern part of the United States. State of things existing at the beginning of the great heats of the first week of July, 1901.

low barometric area in the ocean off Cape Hatteras. This gave a north-to-south circulation, with the formation on July 11th, 12th, 13th, of a decided cyclonic storm center out of the area of low barometer, so that what with the tropical showers, cool northeast winds on shore reaching to the Alleghenies and the dry and cool breezes that moved from out of the Lakes to New England high, a very large section

of the United States experienced marked relief. At the same time while this reversal of the hot-wave mechanism gave relief in the East, the continuance of a circulation from a high pressure over the Gulf into a low pressure over the upper Mississippi Valley kept up the hot wave over the Western States with disastrous results to the crops and with serious effects on humanity. No greater contrast can be afforded, however, in the matter of American weather than that shown on the maps of July 12–13th, or of July 25–26th, which reveal the cool wave circulation at work on the coast giving minimum temperatures of 60, and the hot-wave mechanism still at work in the interior with Kansas, Nebraska, Iowa and Missouri maxima of 104 to 108°.

In studying the mechanism of hot waves here, in Europe, or in Australia, it must be remembered that any one of the determining factors may become the controlling element in the heat-making. At times over the interior valleys of the United States—and this was marked during the hot wave of July 12–26th over the middle Mississippi and Missouri valleys, the corn-belt region—the heat seems to be due to the sheer insolation, the sheer unintermittent sunshine accompanying a circulation that is almost monsoonal in its steady, sluggish movement from the Gulf to the northwest and in a spiral toward the Arizona-Utah "low;" and though there may be no marked "high" over the Gulf, there will be invariably a decided "low" over the west or northwest into which the monsoonal circulation discharges itself, but without rain or any of the normal phenomena connected with "low" areas. Again, the hot wave will seem more particularly to be due to the decided circulation, dynamically heated, from out a "high" which may overlie the Ohio Valley, while at other times, with the circulation not so definitely of the hot-wave type, apparently the checking of radiation is one of the chief factors in a local visitation. Of course, when all three factors combine, then the hot wave is the most intense and of the longest duration. So far as the hot-wave mechanism of Europe goes, insolation under the clear skies of a high barometer is the common type. A hot wave over the British Isles and Scandinavia is caused by a

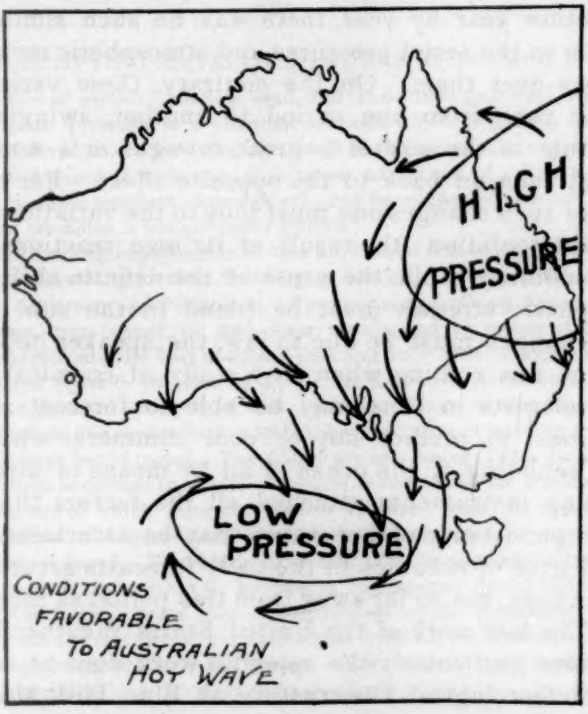
"high" pressure lying over Northern France or a little further north, while France is baked if the "high" lies squarely over it, or a little to the south. In Australia the hot waves which affect the eastern and southern coastal colonies are the result of a circulation from out the heated interior into a "low" lying over the ocean. This north-to-south circulation is, of course, owing to the reversal of things south of the equator, a motion from the heated tropics



Hot-weather conditions for the British Isles and Northwestern Europe. The map represents the primary stage of the hot wave which lasted from the 16th to the 20th of July, 1901, with maximum of 90° in London, and from 93° to 95° on the Continent.

poleward, and is equivalent to our own south-to-north movements, but owing to the character of the Australian continent, the air arriving from the heated interior of Australia is hotter than any of our own sirocco blasts east of the Rockies, so that during the terrible heats of 1896 Australian cities experienced shade temperatures of 122°. Western Europe rarely experiences anything like the heat intensities familiar to Australia and common to the valleys of

the United States, and this is owing to the mitigations due to the aerial circulation from off the ocean. However, owing to the fact that each region has its own critical temperatures for sunstroke and heat exhaustion, temperatures of from 80° to 85° to 90° are fatal in England and Scandinavia and on the Continent. These would be without effect in



In the Southern Hemisphere the movement of the winds out of a "high" and into a "low" is the reverse of that in the Northern Hemisphere. The hot waves of Australia are due to "highs" that overlie the interior and send out scorching winds over the coastal regions, which are the seat of Australian civilization.

the United States where climate tolerance has raised the limit of endurable maxima above 90° for the greater part of the country.

In running over a score and more of lantern slides which were in the form of reproductions of synoptic weather

charts, showing hot-wave conditions in the United States, Europe and Australia, Mr. Watts drove home the lesson as to the essential simplicity of the hot-wave mechanism, its anticyclonic character, and in conclusion pointed out that the map made it clear that local conditions were entirely secondary in the matter of causation. Though the land masses and water masses bore exactly the same relation to each other year by year, there was no such similarity of relation in the aerial pressures and atmospheric movements that lay over them. On the contrary, these varied from year to year, from one period to another, swinging to a maximum in the way of a great drought or a warm winter, and then on back to the opposite effect. For the real cause of such changes one must look to the variations in the general circulation; the result of its own reactions, owing to its mobility, while the cause of the definite shift in the atmospheric stresses must be found in the sun. As all these changes must be due to law, the speaker hoped that the time was coming when by a study of cosmical causes meteorologists in time may be able to forecast seasonal conditions, to predict hot or cool summers, while with better sounding of the ocean of air by means of kites, with recording instruments attached, all the factors that make for the persistency of hot waves may be ascertained and a high degree of accuracy in the daily forecasts secured. We are, perhaps, not so far away from this period as most imagine. The kite work of the United States Weather Bureau, and more particularly the splendid work done at the Blue Hill Meteorological Observatory at Blue Hill, Mass. (ten miles south of Boston), by H. Helm Clayton, under the direction of Mr. A. Lawrence Rotch, where the kites with their meteorographs have sounded the air three miles high, has shown what can be ascertained as to upper air conditions, while Meldrum and Eliot, on the part of meteorologists, and the Lockyers, for astronomers, are making considerable headway in working out the connection between solar conditions and seasonal variations in the weather of the Indian Ocean and adjacent regions. But as no section of the globe is independent in the matter of

circulation, since the highs and the lows, permanent and migratory, interlock the earth around, it is clear that if it becomes possible to forecast the seasons in the tropical and subtropical regions we shall have made a decided step toward discovering a rythm in the seemingly capricious weather of the temperate zones.

SOLIDIFYING METALLIC POWDERS BY PRESSURE.

The "flow of metals" such as lead, and even iron and steel, when subjected to great pressure, is a phenomenon with which engineers have long been familiar and in certain industries, such as the manufacture of lead pipe, hot and cold-punched nuts, etc., it is taken advantage of. The fact, however, that metallic powders, shavings, etc., can be compacted into solid masses by extreme pressures is not generally known.

Some interesting experiments of this kind have recently been conducted in the Workman Engineering Building at McGill University, Montreal, by Professors Anderson and Nicholson. They consist of taking filings or turnings of brass, iron, copper, tin and other metals, and, by means of pressure, securing therefrom solid bars of metal, differing very little in appearance and strength from those to be seen, as a rule, in hardware stores and machine shops. The pressure brought to bear upon the filings or shavings is about 78,000 pounds to the square inch, and this has the effect of welding them into a solid whole or bar of metal. The filings are first encased in a jacket made of steel, which is conical in shape. Pressure is continued for about ten minutes, at the end of which time the tube is removed from the cylinder and opened, when a solid cylindrical bar of brass, lead, tin, iron, or copper, as the case may be, is found. These bars differ very little in appearance from those which have been made either by welding or casting, and appear to be equally strong as the latter. Some idea of the success of the experiment may be gathered from the fact that it has been found quite easy to solidify the filings of Pittsburgh brass, probably the hardest brass manufactured at the present day. This metal is found to yield quite readily to pressure. W.

A NEW WHITE LEAD PROCESS.

It is announced by the *Iron Age* that an extensive new plant principally intended for the manufacture of white lead by a new process is about to be put in operation in Brooklyn. The Brooklyn plant will have a corroding capacity of 12,000 tons annually and a drying and grinding capacity of 15,000 tons. In addition to this the plant will produce also lead oxides, lead pipe, sheet lead and lead traps.

The new process is not in any wise a departure from the principle of the "Old Dutch Process." It consists simply of a method of preparing the lead so as to hasten corrosion. Instead of casting the lead into buckles to be

placed in the corroding pots it is transformed into fine filaments. It is known as the Bailey process, and is said to effect perfect corrosion in three days.

In the Bailey process the melted lead is forced by its own gravity through a perforated plate of thin steel, which forms it into threads or hairs about $\frac{1}{100}$ inch in diameter. The lead solidifies and cools almost as soon as it passes the plate, and is transferred to long shallow trays with slat bottoms. Each of these trays as it receives its charge runs back automatically into place in a suitably constructed bin or rack. When all the trays in this rack have been charged with the fibrous lead the process of corrosion begins. Mingled vapors of acetic acid, moisture, air and purified carbonic acid gas are blown in through suitable openings at the bottom and sides of the rack, and after circulating freely through the mass finally escape. The temperature meanwhile is maintained automatically at the degree most favorable to satisfactory corrosion.

The process is in every respect under absolute control, and any tray with its contents can be withdrawn for examination at any time. Corrosion is completed within three days, and uniformity is more nearly absolute than by any other known process.

The corroded fibres are thrown into water, where they immediately fall into impalpable powder. The cream-like liquid from the disintegrating tank is then run, without the necessity of grinding, into a separating cylinder formed of wire gauze with a mesh of 120 strands to the linear inch. This cylinder is partly submerged in water, and as it revolves the fine particles of corroded lead pass through the meshes, while the uncorroded particles, which in this process never rise above 8 per cent., pass out through the end of the separator and, being in a very fine state of subdivision, are in the best possible condition for conversion into lead acetate and other lead salts. There is therefore no rehandling and remelting of the tailings, as in the ordinary process.

The separated lead is finally washed by flotation, and when dried is ready for sale as dry lead. When intended for sale as lead in oil it requires, of course, a run through the mill; but, owing to the fineness of the product, grinding is necessary only to insure perfect assimilation of the oil.

PHOSPHORESCENT COMPOUNDS FOR LUMINOUS PAINTS, ETC.

Moureto, who has made a careful study of the best conditions for producing phosphorescent compounds, finds that the sulphide of strontium gives pronounced luminosity. His experiments indicate that to produce any phosphorescence it is necessary to have at least 2½ per cent. of active material present in the mixture, and that the phosphorescence increases with the percentage of active substance. The intensity of the phosphorescence may be notably increased by introducing into the mixture used for the production of the compound certain foreign additions. He recommends the use of a mixture composed of barium (or strontium) sulphate, sulphur and carbonates of the alkaline earths, to which, before heating, there should be added small proportions of sodium carbonate, common salt, or bismuth subnitrate. The mixture should be maintained for some time at a cherry-red heat. W.

SINGLE CURVED vs. DOUBLE STRAIGHT JETTIES.

AN APPLICATION OF NATURAL LAWS TO THE REMOVAL OF BARS.

By Lewis M. Haupt.
Member of the Institute.

Vibration is fundamental to the transmission of energy. Heat, light, sound and electricity are propagated by waves of different intensities.

The vibrating pendulum or hairspring marks time; the oscillating piston turns the crank; the vibrating diaphragm transmits the voice. Molecular oscillation within variable limits is a well-recognized law of Nature, even in the transmission of stresses through solids. In fluids it is more discernible in the particles themselves. Hail, snow, dust, sand or rain, driven by wind, seldom pursue a straight course. The path of a storm-center is generally a curved line, while the motion of its elements is in the nature of a cycloid. A river never takes the shortest line to the sea, but oscillates wherever possible, from bank to bank, carving its bed of pools and shoals in such manner as to check and regulate its otherwise destructive energy.

No stream pursues a straight course if it can possibly avoid it, but swings gracefully from side to side, cutting first on the right then on the left, but always on the concave bank, and depositing on the elbows and crossings or points of inversion. Neither do the filaments of the stream pursue parallel paths. The maximum velocity is found near the mid-area of the section, but if these particular particles were to continue uninterruptedly along this course of maximum velocity they would run away from the rest of the water and leave a void. This tendency is checked by a constant interchange of position of the particles which restores the equilibrium by swirls and eddies, cross, and even back currents, in certain sections. It not infrequently happens that water runs up hill, as in the case of a flood when the crest of the wave gives a reverse slope up stream. Such are a few of the

phenomena of flowing bodies, which are well recognized and understood by navigators or others who are familiar with streams flowing between banks; and precisely the same conditions characterize streams in the ocean or other large bodies of water.

Numerous illustrations of this law of running water are within reach of every one.

Every map of the rivers of any country, and especially in alluvial plains; every chart of ocean currents or of tidal estuaries, shows this law to be universal.

The huntsman, fisherman, navigator or traveler on waterways will recall apt illustrations of this law of running water and knows that the deepest water is on the concave side of the bend and not in the cut-off. So true is this, that a pilot navigating a river of which he has no chart invariably hugs the concave banks, swinging from side to side, and is only in doubt as to the channel in the straight reaches between bends.

The drainage rivulets to oceans, lakes or ponds, as they flow across the strand, pursue a serpentine course and not a straight line. The same features are found in the delta mouths of rivers and their passes, which are not straight but which oscillate with variable radii to the sea.

These phenomena have been recognized by some of the most experienced hydraulic engineers of the continent in the treatment of their interior waterways with excellent results.

The following extracts may serve to emphasize the necessity for a close study of this subject on the part of those interested in the development of our commercial highways.

Wheeler, in his "Tidal Rivers," says: "In carrying out works for the improvement of channels in sandy estuaries, it will be found much less costly and more effective to direct and develop the one main low-water channel than to attempt to make a straight channel in a new direction by training regardless of existing circumstances." * * * "By attempting to drive a channel through sands in a direction which nature has not selected will be found costly to carry out and difficult to maintain."

* * * "Straight reaches are not found in practice to preserve the same uniformity of depth as curved channels under the varying conditions of flow to which they are subject."

"In a curved channel the greater velocity and scouring action of the stream is concentrated on one side, preventing deposit altogether, or causing it to accumulate on the convex side only, leaving the greater part of the bed of the river at its full navigable depth.

"A concave bank sets up a scouring action in the current by diverting the particles of the water from their straight course, causing that rotary motion and boring action which occurs in all bends, and which operates in deepening the channel along the concave side.

"From observations made by Mr. H. C. Ripley it was found that in a natural river the water was 58 per cent. deeper in the curved portion of the channel than in the straight reaches.

"Mr. Stevenson says: As a purely abstract question, he, however, was of opinion that it might safely be affirmed that a stream is most likely to follow a permanent course when directed by a concave bank; that the centrifugal force in curved channels has a tendency to draw the greater portion of the water to the concave side, and that the greatest scouring power will be found on that side; whereas in a channel directed by straight walls, the current, having no such bias for either side, is more easily thrown across from side to side.

"Mr. Scott-Russel, in pointing out the evils which had arisen from the abrupt interpolation of portions of straight cuts into gently winding rivers, expressed the opinion that to make part of a natural river straight was a dangerous undertaking; that where the curves were gentle the natural bends should not be interfered with; that a river has an oscillating motion, and there is a similar process going on in it to that which goes on in a pendulous body. A pendulum set in motion continues to oscillate isochronously without the expenditure of any new force, and in like manner, if once a curve or bend was established in a river with considerable current, the mere fact of the commencement of curvature would give it a tendency to continue that curvature, and the stream would go on oscillating regularly to the sea in curves of opposite curvature. Continuity of a system of oscillation should therefore be maintained.

"Captain Culver, speaking of the improvement of rivers, says that straight reaches are strictly to be avoided, more particularly where there is an established business upon the banks of the river to be trained. With a straight reach the deep-water track is acted upon by the most trifling causes, ranging from side to side at will, and it follows that under these circumstances there is no security whatever for the permanency of the deep water, either in a fixed channel or at the shipping berths.

"The commission of engineers employed by the French government to report as to the improvement of the navigation of the estuary of the Seine, in recommending the extension of the training walls through the estuary down to Honfleur, advised that these should assume a sinuous form, having a concave bend leading to the entrance to Honfleur harbor, in order that deep water should be maintained at the entrance jetties.

"M. Fontain, in designing work for the rectification of the Rhine, avoided straight cuts and adopted curves. In the determination of the radii of curvature, he was guided by the inclination and force of the current. General Eads also adopted a curved form for the jetties for the South pass of the

mouth of the Mississippi. In the Weser no attempt has been made to straighten the channel, the existing curves being eased and improved. By cutting off abrupt bends, contracting the width where too great, fixing the course through sands, and deepening where required, a channel may be brought into a uniform condition with a series of gentle curves and rendered serviceable for navigation at far less cost and with better results than by making an entirely new cut. The course may not be so direct in the former as in the latter case, but the want of directness will probably be fully balanced by the more permanent maintenance of a uniform depth throughout, and the greater scouring power of the ebb and flood water."

"The effect derived from training takes time to develop, and the full benefit of the deepening is seldom felt until a considerable period after the work is completed. The benefit to navigation is more quickly realized when the deepening is also assisted by dredging, not only by the actual material removed by the dredger, but also by the disturbance of the material by the buckets assisting its transport by the water.

"Tidal currents will, without any aid from training, keep to the same channel if sufficiently deep. The tendency of all flowing water is to run along the line of the deepest channel, especially if that line is in the direction most favorable for the run of the flood and ebb."

When it comes to the application of these principles, they are so frequently violated with us as to cause a doubt as to whether they are really recognized as fundamental.

To violate a physical law is to cause an injury which can be repaired only at considerable loss by the application of a counter irritant. Nature will constantly seek to restore normal conditions. It is surprising to find mathematical principles so frequently misapplied to physical problems. Because "a straight line measures the shortest distance between two points" it does not follow that two parallel straight lines with currents between them will be better as training walls for a navigable channel than a single curved jetty which aids those currents to carve out and maintain their own channel. Yet it is the almost invariable practice to build two such parallel *straight* jetties or to dredge *straight* cuts in rivers which soon refill and require constant expense for maintenance. At least three times has the cut through the "Cherry Island Flats" in the Delaware river, two miles long, been dredged to 26 feet, mean low water, and just as frequently has it filled almost immediately after, to its ruling depth of 19 feet.

The concave bank practically controls and directs the stream—it is the point of attack for the currents and the point where scour is most rapid. The convex bank is the reciprocal of that where there is virtually no current and where deposit takes place. The continuous change of direction caused by the resistance or reaction of the concave bank, and the consequent differences of velocity of the fluid-particles before and after impart, cause a latteral bottom movement which carries the silt across and on to the convex bank, thus maintaining a deep channel under the concave bend; the depth increasing with the sharpness of the turn.

By maintaining these oscillations by the erection of artificial banks or reaction-jetties across ocean bars the channel may be quickly and cheaply created by natural processes; but great care must be taken in adjusting their curvature and location to the requirements of the particular site, for if placed on the wrong side of the channel with respect to the littoral drift at inlets, they will result in failure.

Thus, a single structure may be made to produce its counterpart, or convex training-bank, which will be automatically adjusted to the regimen of the currents, whether tidal or fluvial, at less than half the cost of the parallel straight jetties, and give a far better and more permanent result, requiring a much smaller expenditure for maintenance.

Such a result has actually been secured at Aransas Pass, Tex., a purely tidal inlet, by an incomplete jetty detached from the shore and placed on the windward side of the channel, as designed by the writer, and the same principles may economically be adapted to the opening of the delta mouths of silt-bearing streams by single concave reaction jetties to better advantage than by two parallel or convergent jetties. Such designs would appear to conform to the laws of flowing bodies, and would not do violence to nature, but, on the contrary, assist her operations.

ELECTRICAL RECOVERY OF PURE TIN FROM WASTE TIN CUTTINGS.

Gelstharp.—An illustrated description in detail of a process which is said to have been successful in a practical trial. The tin is recovered by electrolysis, and the clean iron is either sold as best scrap or converted into green copperas, which may be further converted into red oxide and Nordhausen sulphuric acid, the profits derived therefrom being exceptionally large. The electrolyte in the stripping tanks is a 1¼ per cent. solution of commercial hydrochloric acid, to which is added a small quantity of oil of vitriol.—*Elec. Chem. and Met.*

TESTS OF ALUMINUM BRONZES.

Tetmayer gives an account of tests made in the Zurich Polytechnic School at the request of the Neuhausen Aluminum Company, which provided the samples. The specific gravity first rises and then falls, as the percentage of aluminum increases. The maximum strength for soft alloys was obtained with 3·4 per cent. Al, and for hard alloys with 1·4 per cent. Al. For brass, the elasticity decreases with the increase of Al, and is extremely low with 2 per cent. of the latter. Silicon increases the specific gravity and reduces the elasticity. Iron, in the proportion in which it was present in the alloys, was not observed to sensibly influence the physical characteristics. Aluminum bronze, containing 10 per cent. Al with 1·5 per cent. Si and Fe, is too brittle to be of any practical value. As regards the abrasion by friction, the hard alloys, with less than 89·6 per cent. Cu, lose little in weight, while the soft alloys, with less than 6 per cent. Al, heat and wear away rapidly.—*Rev. de l'Elec.*

AGE OF THE STONEHENGE MONUMENTS.

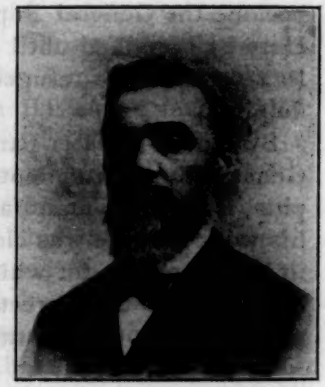
The work of raising the Great Monolith at Stonehenge, England, has enabled archæologists to form a more reliable estimate regarding the epoch in which these druidical monuments were erected. There has hitherto been much controversy on this point, certain authorities clinging to the assertion that it was built in Roman times, while others contend that it was erected during the bronze period. While making excavations round the monolith for the concrete bedding, a large number of neolithic stone implements were unearthed that show every sign of having been used to cut and to square the stones. They all bore marks of hard working, and when of no further use for cutting, the stones had been apparently thrown aside and afterward used to make a bedding to support the uprights. Experts therefore now entertain little doubt that Stonehenge was built in the neolithic age, for had it been built in the bronze or iron age, bronze or iron tools would have been used. Although leading authorities do not quite agree as to the actual date of the introduction of bronze into Great Britain, it is generally conceded to have been about 1500 B. C. It is consequently apparent that Stonehenge must have been constructed at some period considerably previous to that date.—*Scientific American.*

IN MEMORIAM.

LUTHER R. FAUGHT.

Among the many members of the Franklin Institute who have won wide distinction and honor for meritorious inventions in science and the mechanic arts, Luther R. Faught holds a high rank. His inventions in the mechanical field have been both numerous and valuable. It is fitting, therefore, that a brief record of his life-work should be read before the Institute and published in the *Journal* for permanent record.

Luther R. Faught was born in Sidney, Me., on the 22d of February, 1828. He was of German extraction, his ancestors settling in America in 1751.



LUTHER R. FAUGHT.

His early life was spent on his father's farm. But it was the blacksmith's shop and wagon factory, necessary adjuncts to all large farms in those early days, that possessed the chief charm for the growing lad. Here, during the evenings, for the daylight was almost wholly spent in farm work, he first evidenced that mechanical genius which so characterized his after-life. Here, among other rude triumphs, achieved under these circumstances, he produced a model of a reaping machine, said to embody principles similar to those of the McCormack reaper. This model is still in existence.

But the farm and its environs at last grew too circumscribed for the young inventor, so we find him at seventeen years a runaway from home. A working capital of ten cents, added to a muscular activity, which served him so well in later years, carried him to Augusta, Me., where he found, in the machine shop of Rufus Wolcott, employment

more suited to his tastes. Here he remained for three years until he learned his trade as machinist. He then went to Dover, N. H., where he joined himself with the firm of Hanson & Ogden. On the dissolution of the partnership of this firm he went to Macon, Ga., where he was engaged by Robert Finley as Superintendent of his machine shop. It was while engaged in this work that he took out his first patent on November 1, 1853. This invention was for an automatic steam governor, in which the first attempt was made to employ the frictional resistance which the governor has to overcome as the means by which its movements are controlled. Though not a complete solution of the difficulty, yet it was in a direction that led to the perfection of the class of governors to which it belongs.

In 1855, Mr. Faught went to Atlanta, Ga., where he became the General Superintendent for the Winship Bros. Here he remained until the War of the Rebellion, in 1861. In 1865, he was a refugee to the North, and settled in Philadelphia.

By far the greater part of his working life was spent as General Superintendent of A. Whitney & Son in Philadelphia, car-wheel manufacturers. During the early part of his work here he was closely connected with improvements in horse-powers, for which he took out numerous patents. His work in this direction fairly revolutionized the former methods of cotton ginning in the South.

It will be seen, from an inspection of the list of patents taken out by Mr. Faught, appended to this notice, that between 1866 and 1884, some of the more important are for a hold-fast for lathes; a boring bar, which markedly increased the output of a machine for boring the hub of a car wheel; and a round woven pulley belt.

After leaving the Whitneys, he was employed by Bement, Miles & Co., Philadelphia, where he remained from October 24, 1892, to March 2, 1894. Here he acted as general utility man in the mechanical department. His especial duty was to improve foundry methods, especially the mixing of irons to suit the various requirements of the work. In this work he was eminently successful.

His invention for improvements in mining car wheels was for a device which enabled a wheel for mining and other purposes to be fitted to run loose on an axle without the necessity and expense of collars on the axle. This improvement prevented the access of dust and grit to the running parts, while at the same time it permitted the bearings to be oiled with a minimum of lubricant. The wheel hub, closed on its outer end, was provided with both a recess, into which a key block is dropped, and with an oil chamber. Each end of the axle was turned with a groove, into which the key block falls when the wheels are in position, and in which they are secured by the plugs which close the oil chambers. Wheels, built in accordance with these improvements, were exhibited by A. W. Whitney & Son, at the Novelties Exhibition of the Franklin Institute, in Philadelphia, in 1885. At the same exhibition another invention of Mr. Faught was shown. This was an improved pedestal to secure the axle to the body of the car, and so constructed as to exclude dust from the inside face of the hub.

Perhaps the most valuable invention of Luther R. Faught was that of the radial expansion chill made sometime late in 1875, or early in 1876. This important invention was not patented, either by reason of some mistaken idea that through his employment by the Whitneys he was not entitled to patents for inventions of his own on car wheels, or, possibly, for reasons best known to himself, he deemed it undesirable to thus assert his rights. There is, however, no doubt as to his invention of the contracting chill. The Whitneys themselves acknowledge his right to the invention, as will be seen from the following, taken from the issue of the *Locomotive Engineer* for November, 1888:

"*Editor The Locomotive Engineer:*

"Referring to the article entitled 'Hard Tests of Chilled Wheels' in your issue for October, we beg leave to say that the honor of having invented the first contracting chill of which we have any knowledge is due to Mr. L. R. Faught,

Superintendent of our mechanical department. It was made in 1876.

"The Whitney contracting chill was invented by the present senior member of this firm in 1885.

"A. WHITNEY & SONS.

"PHILADELPHIA, PA."

This Faught contracting chill was in all respects a pioneer invention; and provided an entirely new means for ensuring the desired result. As in the case of nearly all such inventions it had rival claimants; but, without entering again into a controversy that has long since been fairly settled, the honor of the invention has, by the concensus of authoritative opinion, properly been awarded to Luther R. Faught. In the manufacture of car wheels the essential requirements are long and smooth running so as to increase, as far as possible, the duty of the wheel in satisfactory car-miles. To insure this, the wheel, when manufactured, must not only possess accurate roundness, but must have its tread and flange uniformly hard so as not only to resist rapid wear but also to ensure uniform wearing under prolonged use. To ensure hardness to the wearing surfaces of the wheel it is necessary to provide the mold of the wheel with a chill, that shall effect a uniform and rapid chilling or cooling of the molten iron when poured into the mold.

Before the pioneer invention of Faught's radial contracting chill, it was customary to provide a fairly heavy cast iron ring, whose inner surface was turned out so as to conform to the shape of the tread and flange of the wheel to be cast. The ring was provided at suitable points with handles or lugs for convenience in handling. Though this primitive form of chill ensured a hardened or chilled surface, due to the sudden chilling of the iron on coming in contact with the cool surface of the ring, yet it was unsatisfactory, because, either on account of differences in thickness of the ring, where the lugs or handles were located, or by reason of other peculiarities in construction, the hardening was far from uniform throughout. Moreover, the chill

did not expand uniformly throughout, so that parts of the chilling surface remained in contact with the cast wheel longer than others, thus not only producing unequal chilling, but also resulting in a warping of the surface of the mold and a consequent change in the shape of the wheel. Moreover, the unequal stresses caused by unequal and excessive expansion of the chilling surface, resulted in its breaking up and disintegrating, thus injuring the smoothness of the chill surface and necessitating frequent renewals of the chill.

In order to overcome the tendency of the solid-ring chill to increase its diameter unevenly and thus produce unequal chilling and irregularities of shape of the car-wheel, Mr. Faught invented the radial contracting chill by providing segmental chilling blocks united to a continuous outer ring, cast in a single solid piece by expansion-bars forming a radial web. There was thus provided an inner and an outer ring connected by radial arms, the inner ring being divided between the arms, each radial spoke or arm supporting a segment of the inner ring. When heated, the expansion of these radial spokes carried the inner ring towards the center, thus ensuring efficient chilling by keeping the chill in contact with the tread of the wheel, both for a longer time and more uniformly than in the old form of chill.

Working along these original lines the inventor produced a chill in which the effect of expansion, instead of withdrawing the chill surface from the face of the wheel, through the radial expansion of the bars, caused this surface to contract, thus continuing its chilling effect on the tread of the wheel. Generally, therefore, Mr. Faught's great invention in chills for car wheels consisted in means whereby the expansion of the metal caused the chill to move towards the wheel, instead of, as in all earlier forms, away from it. On this fundamental and radically new departure, all subsequent operative improvements in chills for car wheels have been founded. A wheel cast in a chill of this form was exhibited by A. W. Whitney & Son's, at the Centennial Exhibition, in Philadelphia, in 1876.

Although this early form of contracting chill constituted an immense improvement over anything that preceded it, yet it manifested a tendency to lose its true shape, not only from the rough handling of the foundry, but especially because the inner-ring section, being firmly clamped between the cope and drag, lost its free movement. At a later date, 1886, Mr. Faught remedied this defect by tying the arms together alternately at top and bottom. A subsequent improvement, made in 1887, consisted in what is called "the suppression of the mold," in which the outer ring was clamped between the cope and drag, enclosing the space between the arms in the mold, thus leaving the inner ring of sections quite free to move inwards, since they were devoid of any clamping.

In a letter to the *National Car and Locomotive Builder*, of June, 1889, in discussing the cause of uneven chilling of car wheels, and the value of the contracting chill for preventing the same, Mr. Faught thus contrasts the old and improved forms of chills:

"*Editor of the National Car and Locomotive Builder:*

"In the last (May) issue of your journal you refer, under the title 'The Cause of Uneven Chilling,' to the value of contracting chills as a preventative. As the original inventor of contracting chills, permit me to add a few lines relative to the subject.

"The *construction* of the solid-ring chill determines that it shall increase its circumference, and hence its diameter, under the influence of heat; the *inequality of clamping* the chill in combination with the cope and drag, determines that this increase shall be in a varying degree around the circumference, causing both uneven chilling and loss of superior roundness in the wheel. To overcome these defects I invented the chill now known as the contracting chill, composed of segmental chilling blocks united to a continuous outer ring, by a radial web of expansion bars; and cast as its predecessor, the solid ring, in a single piece. The common mode of clamping the contracting chill with the cope and drag resting upon the inner section, I found

did not allow the segmental blocks sufficient freedom of action, and therefore as the difficulty was not removed as fully as I desired, I invented a cope and drag with a method of clamping which did away with all restriction of movement to the inner section . . ."

In a later invention Mr. Faught greatly increased the efficiency of his contracting chill by a device which practically increased the length of the radial bars, without proportionately increasing the size of the chill. It is evident that the longer these bars are, the greater is the contraction that is obtained before the outer ring becoming heated expands and tends to draw the chill away from the radius of the wheel. The inventor effected this lengthening of the radial bars, or arms, by what he calls *secant-bars*, or straight bars inclined to the segments of the inner ring; instead of at right angles thereto, as in the original form. The secant-bars were interlocked like the girders of a bridge. Chills constructed on this principle are more efficient in action than those of the earlier type.

The *Locomotive Engineer* for January, 1889, referring to the invention of the contracting chill, very correctly says of Mr. Luther R. Faught:

"His invention goes back to 1876, and his patents nearly as far. Mr. Faught is to the contracting chill what Howe was to the sewing machine, Whitney to the cotton gin, Ericsson to the screw propeller, and Jethrow Wood to the common plow—the pioneer."

From 1896 to 1901, Mr. Faught was employed by the Lobdell Car Wheel Company, of Wilmington, Del. This engagement began July 27, 1896, and continued until his death on November 23, 1901, for a period of over five years. His duties with the Lobdell Car Wheel Company were confined principally to matters connected with his patent self-oiling wheel and the contracting chill.

Marked inventive ability in the mechanical line was the characteristic of Luther R. Faught. His numerous patents were for inventions that were eminently practical and useful, and many of them have come into extended use.

EDWIN J. HOUSTON.

PHILADELPHIA, DEC. 23, 1901.

LIST OF PATENTS FROM 1853 TO 1901.

No. 10,185, Improved Regulators of Steam Engines. Patented November 1, 1853.

No. 25,497, Improvement in Horse-power Machines. Patent dated September 20, 1859.

No. 60,163, Turning Lathe, December 4, 1866.

Reissue No. 4,390, Turning Lathe. (Patent No. 60,163, dated December 4, 1866). May 23, 1871.

No. 115,290, Hold-Fast for Lathe Spindles, May 30, 1871.

No. 115,291, Die Stock for Cutting Screws, May 30, 1871.

No. 119,681, Cog Gearing, October 3, 1871.

No. 120,048, Horse-power, November, 21, 1871.

No. 123,774, Horse-power, February 20, 1872.

No. 132,205, Pulley Belt, October 15, 1872.

No. 143,974, Horse-power, October 28, 1873.

No. 151,213, Horse-power, May 26, 1874.

No. 152,222, Horse-power, June 23, 1874.

No. 169,975, Car Axle Box, November 16, 1875.

No. 220,441 (Sproull and Faught) Car Axle, October 7, 1879.

No. 241,481, Boring Bar, May 17, 1881.

No. 241,482, Boring Bar, May 17, 1881.

No. 241,483, Machine for Boring Metal, May 17, 1881.

No. 243,234, Worm and Worm Wheel Gearing, June 21, 1881.

No. 253,523, Boring Bar, February 14, 1882.

No. 255,846, Boring Bar, April 4, 1882.

No. 257,157, Clamp for Stationary Spindles, May 2, 1882.

No. 260,467, Shaft Coupling, July 4, 1882.

No. 260,468, Shaft Coupling, July 4, 1882.

No. 262,212, Device for Lubricating Loose Wheels and Pulleys, August 8, 1882.

No. 289,522, Boring Bar, December 4, 1883.

No. 302,831, Boring Tool, July 29, 1884.

English Patent No. 11,577, Continuous Cutter, September 29, 1885.

English Patent No. 11,578, Car Wheel, September 29, 1885.

Canada Patent No. ——, 1890. Car Wheel Chill.

No. 311,652, Boring Bar, February 3, 1885.

No. 321,590, Car Wheel, July 7, 1885.

No. 327,148, Metal Boring Bit, September 29, 1885.

No. 327,149, Device for Holding Metal Cutters, September 29, 1885.

No. 327,150, Car Wheel, September 29, 1885.

No. 327,151, Device for Holding Metal Cutters, September 29, 1885.

No. 341,326, Chill for Car Wheels, June 28, 1887.

No. 365,590, Chill for Car Wheels, June 28, 1887.

No. 365,914, Chill for Car Wheels, July 5, 1887.

No. 402,664, Chill for Car Wheels, May 7, 1889.

No. 477,524, Chilled Cast Iron Car Wheel, June 21, 1892.

No. 588,325, Mine Car Running Gear, August 17, 1897.

No. 588,326, Mine Car Running Gear, August 17, 1897.

APPLICATIONS NOW PENDING.

(*a*) Car Wheel, Serial No. 76,449, filed September 29, 1901.

(*b*) Car Wheel, Serial No. 76,450, filed September 25, 1901.

Cores for Casting Car Wheels, Serial No. 77,230, filed October 2, 1901.

(*a*) Issued as Patent No. 687,453. November 26, 1901.

(*b*) Issued as Patent No. 687,454, November 26, 1901.

NOTES AND COMMENTS.

MARBLE IN ALASKA.

J. E. Cronin, who has recently returned from Marble Creek, on Prince of Wales Island, and W. K. Sheldon, who has just joined him from San Francisco, have some wonderful stories to tell of the fine character of the marble to be found at Shakan, on Prince Edward Island. The marble is said to be equal to the best Italian marble. Mr. Sheldon said: "When I received samples of this marble last February I saw at once that it was unlike any marble now being produced in the United States, but identical with the marble produced in the world-famous quarries of Carrara, Italy. While there are a number of profitable quarries in the United States and a large amount of American marble is used, yet the Italian product has always occupied a field which no American marble could fill, as evidenced by the fact that during the fiscal year ended June 30, 1900, nearly 40,000 tons of Italian marble were imported into the United States. This marble from Alaska, in texture, color and chemical analysis, is identical with the Carrara deposit, and there is no

reason why it should not supplant the foreign product entirely. I went to Alaska in March and found a mountain of high-grade marble. While I was fully convinced as to the quality of the material, I did not wish to make a final report on the property as a commercial proposition until large blocks had been quarried, taken to the market and sawed. We, therefore, quarried a number of blocks, and I took them to San Francisco and had several of them sawed. These blocks, of course, were taken from the surface of the ground, and, having been subjected to climatic influences for several centuries, were soft for a depth of several inches from the surface; but the trial demonstrated the fact that the deposit is a remarkably sound one, and I have every reason to believe that the percentage of high-grade sound marble will be much larger than in any of the deposits now being worked in the United States. In fact, when you consider that in developing marble quarries it is customary to take out and throw away from 10 to 20 feet of the surface material, the results obtained are unprecedented. The amount of the matter is that on an island in southeastern Alaska, within a few feet of deep water, there is a larger area of high-grade marbles than the combined area of all the quarries now being worked in the United States"—*Seattle Post-Intelligencer.*

THE GOLDSCHMIDT WELDING PROCESS.

The application of the Goldschmidt welding process for welding rails has lately undergone a simplification, according to a report in the *Zeitschrift des Vereins Deutscher Ingenieure*, Vol. XLV., p. 1545. The curcible in which the required quantity of thermite is to be melted is made in the form of a funnel, about 16 inches in height and 12 inches in diameter at the top. The bottom end is provided with an opening about ¾ to 1 inch in diameter, which serves as a pouring hole. An iron plug is used to close the hole during the reaction, and the hole is freed preferably by knocking this up into the liquid mass, when it is at once fused. In this way the precise moment for discharging the contents is easier to regulate than by allowing the plug to remain in position until melted out. The top of the plug should be covered with a little fine dry sand to prevent it burning out too soon. After filling the crucible, the open upper end is covered with a metal hood, provided with a hole, through which the contents are ignited. This arrangement has the advantage that the metal flows into the mold before the slag, whereas in ordinary crucible the slag always runs off first. The loss of heat by radiation is much reduced, and the lining is not exposed for so long to the heat of the thermite, since the time it remains in the crucible is no more than what is just required for the reaction—that is, a few seconds only. In welding objects, the surface on which the thermite is poured is first cleaned with a file, but the abutting ends of the rails or bars need not be touched at all.

Further applications of the Goldschmidt method for the production of high temperatures are described by H. Goldschmidt in *Stahl and Eisen*. Its use in welding is especially referred to, and it is pointed out that through its aid chromium and maganese are now being manufactured on a commercial scale. The manufacture is effected in a large crucible-like vessels in which some hundredweights of the metal are made at each operation. The reaction

is so rapid that this operation requires only about half an hour for its completion. While the carbon-free chromium made is utilized in particular for steel, the pure manganese is used for the manufacture of copper manganese alloys. Up to now the only form in which chromium has been available to the steel manufacturer was as ferrochrome, containing from about 40 to a maximum of 65 per cent. of chromium. This product contains usually from 10 to 12 per cent. of carbon, calculated on the chromium contents. The chromium is, therefore, present in ferrochrome, not as the free metal, but as a chromium carbide. All steels, therefore, that are produced with the aid of ferrochrome are, strictly speaking, not chrome steels, but chrome-carbide steels. With the pure chromium other alloys can therefore be made which have other properties. Thus, for instance, they are less hard. It is possible, too, by the use of metallic chromium, to make chrome steels with a much higher chromium contents than has been hitherto possible, owing to the simultaneously high carbon contents which would otherwise have to be present. In the open-hearth process the chromium is added toward the end of the operation; at a time, that is, when the introduction of impurities is most objectionable. The loss by oxidation when high percentage ferrochrome is used amounts to from about 20 to 25 per cent., but is considerably less when pure chromium is employed. If it is a question of producing chrome steele of, say 2.5 per cent. chromium, and with 0.2 or even 0.1 per cent. of carbon pure chromium must be employed. Otherwise the carbon contents could not be kept below 0.30 or 0.35 per cent. In the manufacture of crucible cast-steel also, when it is desired to produce a metal with only from 1 to 2 per cent. of chromium, the metallic chromium is especially valuable. Further, in the case of the manufacture of high chromium tool steels, with 6 to 10 per cent. of chromium, metallic chromium is utilized. One works is indeed endeavoring to increase still further the chromium contents in metal to be used for tool steel.

Metallic manganese has not found the same application to steel manufacture as has been the case with chromium. In the first place, manganese steels have been less in evidence than chrome steels, and then, too, the relatively high cost of the metallic manganese has stood in the way of its utilization. Thus its cost, as compared with the ferromanganese commonly employed, is about ten times as great. It has, however, been largely utilized of late in the manufacture of alloys with copper. Pure manganese oxidizes very slowly in the air, and forms alloys with considerable facility.

The Goldschmidt method is used also to manufacture pure alloys of iron and manganese with titanium. It is possible to produce in this way alloys of iron and manganese containing 40 per cent. of titanium, but these only melt at so high a temperature that it has not been found desirable to make the commercial product contain more than 20 to 25 per cent. of titanium. The addition of this alloy to the iron must be effected at a high temperature. Such small additions of titanium as a few tenths per cent. are stated to give iron and steel a very tough, fibrous structure. It has recently been found that titanium will alloy much more freely with manganese than with iron, and instead of the ferrotitanium a manganese titanium with from 30 to 35 per cent. of titanium has been made. If this alloy is used, twice as much manganese is introduced into the metal under treatment. As, however, usually

only 0.1 to 0.2 per cent. of titanium is required, the additional manganese contents does not matter. This manganese-titanium is more readily dissolved by ingot iron than the iron alloy. A better method of introducing the titanium consists, however, in its addition in a nascent state, by the addition of so-called manganese-titanium thermite to the ladle containing the molten iron. The titanium takes up dissolved nitrogen, the resulting red crystals having been subsequently found by micrographic investigation.—*The Iron Age.*

BOOK NOTICES.

A Manual of Volumetric Analysis. Treating on the subjects of Indicators, Test-Papers, Alkalimetry, Acidimetry, Analysis by Oxidation and Reduction, Iodometry, Assay Processes for Drugs with the Titrimetric Estimation of Alkaloids, Estimation of Phenol, Sugar; Tables of Atomic and Molecular Weights. By Virgil Coblentz, Ph.D., Phar.D., F.C.S., Professor of Chemistry in the New York College of Pharmacy. Illustrated. Published by P. Blakiston's Son & Co., 1012 Walnut Street, Philadelphia, 1901. Octavo, 180 pages. (Price, $1.25, net.)

Chapter I is devoted to definitions, apparatus, and standard solutions. Chapter II treats of Analysis by Saturation, and describes indicators, test-papers, the preparation of standard acid and alkali solutions, alkalimetry, acidimetry, direct percentage estimators, empirical solutions in titrating, volumetric estimations of alkaloids. Chapter III is devoted to Analysis by Oxidation and Reduction, and treats specifically of estimations with potassium permanganate, direct and indirect methods of estimation with potassium dichromate, determinations involving iodine and sodium thiosulphate V. S., estimation of free iodine and iodometry. Chapter IV is devoted to Analysis by Precipitation, treating of the estimation of combined halogens, their acids and solutions of silver nitrate and sodium chloride V. S., Volhard's or thiocyanide method. Chapter V treats of the estimation of phenol, and the volumetric estimation of the sugars. An Appendix gives some useful tabular data. W.

Practical Calculation of Dynamo-Electric Machines. A manual for electrical and mechanical engineers, and a text-book for students of electrical engineering. By Alfred E. Wiener, E.E., M.E. Second edition revised and enlarged. 8vo, cloth, pp. 750, 390 illustrations and 125 tables. New York: Electrical World and Engineer, 1902. (Price, $3.00.)

Part I. Physical Principles of Dynamo Electric Machines, two chapters. Part II. Calculation of Armatures, eight chapters. Part III. Calculation of Magnetic Flux, three chapters. Part IV. Dimensions of Field-Magnet Frames, three chapters. Part V. Calculation of Magnetizing Force, two chapters. Part VI. Calculation of Magnet Windings, four chapters Part VII. Efficiency; Calculation of Dynamos, Motors, and Motor Generators, six chapters. Part VIII. Practical Examples of Dynamo Calculation, two chapters. Appendices: I. Table of Dimensions of Modern Dynamos. II. Wire Tables and Winding Data. III. Dynamo Specifications. IV. Remedies for Sparking Due to Various Causes. W.

Water-Tube Boilers. Based on a short course of lectures delivered at University College, London. By Leslie S. Robertson, M. Inst. C.E., etc. (With upwards of 170 illustrations.) 8vo, pp. XV + 213. New York: D. Van Nostrand & Co., 1901. (Price, $3.00.)

Chapter I of this work defines the water-tube or tubulous boiler and presents some historical data. Chapter II treats of circulation in water-tube boilers, the rate of heat transmissions, ratio of heating surface to greater surface efficiency of heating surface, and forced draught. Chapter III is given up to the description of individual types of large tube boilers of this class. Chapter IV describes similarly the small tube boilers; and Chapter V consists of boiler accessories, such as reducing valves, steam separators, feed-water heaters, etc. W.

Electro-Magnets: their design and construction. By A. N. Mansfield, Sc.B. (Van Nostrand's Science Series, No. 64.) New York: D. Van Nostrand Company, 1901. (Price, 50 cents.)

The above-named work is a completely revised edition of No. 64 of "Van Nostrand's Science Series," originally entitled, "Electro-magnets, the Determination of the Elements of their Construction," by T. H. du Moncel.

Encyclopèdié Scientifique des Aide-Mémoire. Librairie Gauthier-Villars, Paris, France.

Since our last notice of this work, the following volumes have been issued:

Vigneron (Eug.), Ingénieur, ancien Professeur à l'École supérieure d'électricité.—Mesures électriques. *Essais industriels.*

Equevilley (R. d'), Ingénieur civil des constructions navales, ancien Ingénieur aux Forges et Chantiers de la Méditerranée.—Les bateaux sous-marins et les submersibles.

Minet (Ad.), Ingénieur chimiste, Directeur du Journal *l'Électrochimie.*—Galvanoplastie et Galvanostégie.

Astruc (*H.*), Ingénieur agricole, Préparateur à la Station œnologique de l'Aude.—Le vin.

La Convention du Mètre et le Bureau International des Poids et Mesures. Par Ch-Éd. Guillaume. Paris: Gauthier-Villars, 1902. 4to, pp. 238.

Following closely upon the appearance of Bigourdan's valuable historical work, "*Le Système métrique des Poids et Mesures,*" this beautiful volume forms an admirable supplement to it.

After a brief review of the origin of the metric system and the progress made in metrology from that time to the establishment of the International Bureau in 1870, the author proceeds to describe the laboratories of the Bureau at Sèvres, near Paris, and their elaborate instrumental equipment.

The following chapters are devoted to a detailed account of the researches and other activities of the Bureau during the quarter of a century which has elapsed since these laboratories were inaugurated.

In the main part of the book Dr. Guillaume describes and discusses in a most interesting manner the development of methods and instruments used in the construction standards of length and mass, as well as the auxiliary measurements of temperature and barometric pressure.

In much of this work, as is well known, he has been conspicuous as one of the most active and successful members of the staff of the Bureau, but he accords the fullest measure of credit to his associates, irrespective of their nationality. It is pleasing to note in this connection his appreciation and extended account of the work of our fellow-countryman, Professor Michelson, of determining the wave-lengths of certain radiations (of the cadmium spectrum in particular) in order to fix the length of the meter in terms of a constant of nature, an investigation which resulted in determinations of "a certainty and precision hitherto unknown."

The remaining chapters deal with some special investigations conducted by the Bureau, and the decisions of the International Committee. There are also some appendices relating to various matters of interest in connection with the use of the metric system.

The book may be recommended not only as an admirable *résumé* of the labors of the International Bureau of Weights and Measures, but also as a lucid and scientific account of the state of metrology at the beginning of the twentieth century.

Its value is greatly enhanced by numerous excellent illustrations.

H. F. K.

Franklin Institute.

[*Proceedings of the Stated Meeting held Wednesday, March 19, 1902.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 19, 1902.

President JOHN BIRKINBINE in the chair.

Present, 118 members and visitors.

Additions to membership since last report 12.

The Actuary reported, by direction of the Board of Managers, the loss of one of its members, Mr. Stacy Reeves. The Actuary likewise presented a report of a Special Committee of the Board to devise means of increasing the revenues of the Institute. This report, which received the endorsement of the Board, recommended an increase of the annual dues of the various classes of members.

By direction of the Committee on Science and the Arts, the Secretary reported a proposed amendment to the By-Laws, increasing the number of the Committees' members from forty-five to sixty, of whom twenty shall be chosen each year.

Prof. Lewis M. Haupt presented a communication on "The Curvilinear Currents," which was freely illustrated by lantern slides.

Mr. F. E. Ives followed with a description of "A New Photo-Micrographic

Process." Mr. Ives illustrated his apparatus and methods. Referred to the Committee on Science and the Arts.

Mr. Morris Earle, for Messrs. Williams, Brown & Earle, described a new form of light adapted for the stereopticon and also for a variety of photographic work.

Mr. Earle projected satisfactorily a number of lantern slides with this light in a single, and also in a dissolving, magic lantern. He also exhibited a convenient form of bromide enlarging apparatus, using the same light, by means of which either the professional or the amateur photographer is enabled to make bromide enlargements of any size, and in a shorter time than is ordinarily required. By a simple change in this apparatus, and the use of an ordinary hand-camera, it can also be employed for the making of lantern slides from negatives of any size.

The new light is also arranged on a pedestal stand with a parabolic illuminator, by means of which photographic copying and photo-engraving work can be done rapidly and cheaply.

The "Bright White Light" apparatus consists of a steel tank, in which is placed a few quarts of kerosene oil; air is pumped into the tank by means of a small bicycle pump to a pressure of 60 pounds. This pressure forces the oil through a slender tube to the lamp, whence it escapes through a minute aperture into the vapor tube. The vapor tube is first heated by igniting a spoonful of alcohol beneath it; afterward the heat is maintained by a Bunsen flame in the lamp itself. In this hot vapor tube the oil is instantly converted into vapor, mixed with the air and driven by pressure into the burner, where it produces a brilliant light.

Three quarts of kerosene oil, it is claimed, will run the light for twenty-four hours. It is recommended by the makers because of its portability (the entire weight of the apparatus being only ten pounds), its cheapness and ease of operation.

Mr. W. N. Jennings followed with an exhibition of a series of lantern slides which he had made, representing some characteristic local scenes during the recent storms and floods.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, February 5, 1902.*]

MR. LOUIS E. LEVY in the chair.

The following reports were adopted:

(No. 2149.) *Molding Machines.*—Harris Tabor, Edgar H. Munford and Wilfred Lewis, Philadelphia.

ABSTRACT.—These machines are the subject of a number of patents granted to Tabor in 1895, to Tabor and Munford in 1897, and more recently to Lewis, reference to which is made in the report.

The various devices have been carefully examined, and one of them has been observed in daily work for about a year in a large foundry in this city where several other forms of power molding-machines are used.

One man, an unskilled operator, is now turning out at this foundry from seventy-five to one hundred and ten molds per day in snap-flasks, the output depending somewhat on the character of the patterns. A skilled operator in the same foundry will put up about one-half of this number of flasks from the same pattern per day. In making 2½-inch and 3-inch oil dishes, which are exceedingly thin castings (about ⅛-inch thick, 1¼ inches long, 2½ inches deep), the same operator will set up about eighty flasks per day as compared with twenty similar molds made by hand.

The Tabor Vibrator Machine is of two distinct types, viz, the "Split Pattern Vibrator Machine" and the "Vibrator Frame Machine," where solid patterns are attached without change to protecting carriers to a frame to which is attached the vibrator, by which means the patterns are handled and drawn from the finished mold. Both of these types are built for either hand or power ramming.

The patterns may be changed on either the "Split Pattern" or the "Vibrator Frame" machine very quickly—in some cases in less than three minutes—and a large day's work has been made with even changes of patterns during the day. In one foundry, where a number of these machines are installed, it is not unusual to send patterns to be fitted to the Tabor Machine to make a single mold. In these machines "stripping-plates" have been practically abandoned, for stripping-plates, when properly used, are expensive.

The advantage of the Tabor Machine of the "Split Pattern" type is shown by a statement that, given a set of split patterns, these may be fastened directly to the pattern-plates or machine and used without change, whereas, with other forms of machines embodying stripping-plates, these patterns must be fitted to what are known as building-down pieces, plane top and bottom, and the stripping-plate must be brought accurately to the joint-surface and cut exactly to the outline of the pattern at this surface.

When new and special patterns are made for the Tabor Machines, they are of much cheaper form than the costly appliances which are required on all other machines which combine good work with pattern-drawing mechanism.

In conclusion, the investigators report that the Tabor Vibrating Molding Machines, using either split or undivided patterns without stripping-plates, mark a distinct and valuable improvement in the art of molding. The Scott award is recommended. [*Sub-Committee.*—A. E. Outerbridge, Jr., Chairman; Wm. C. Henderson, Robert Job.]

(No. 2152.) "*Star*" *Ventildtor.*—Henry O. Herman. (Referred by the Judges of the National Export Exposition.)

ABSTRACT.—The apparatus is intended to be attached at the top of buildings or flues, and to utilize any current of air that may be blowing, for the purpose of creating an upward current through the ventilator. (The details unintelligible without an illustration.)

The committee named to make the investigation made some experiments with a 10-inch ventilator of this construction to determine its suction-power

under various conditions, and found that the quantity of air discharged was sufficient to satisfactorily ventilate a room to which it might be applied.

The report recommends the award of the Scott Legacy premium and medal. [*Sub-Committee.*—H. W. Spangler, Chairman; T. Carpenter Smith, J. M. Emanuel, Wm. McDevitt.]

(No. 2194.) *Method of Making Large Objects from Aventurine Glass.*—Edward M. and Sydney B. Walsh, Janvier, N. J.

ABSTRACT.—The process is covered by U. S. patent, No. 629,973, dated August 1, 1899, granted to applicants and involving the production of aventurine glass in masses of such size as to be suitable for the manufacture of large objects, such as slabs, tiles, plaques, etc., which, hitherto, has not been accomplished.

The new process consists substantially in melting together in a muffle furnace in a suitable mold a quantity of selected fragment of the glass, with exclusion of the air, the mold corresponding approximately to the size of the sheet desired. When melted, the fragments form a compact mass, which is previously cooled and molded, and finally cut and polished in the usual way.

The inventors submitted specimens of their product in the form of slabs of considerable size.

In view of the novelty of the process, and the new and valuable properties of the product, the Scott award is recommended. [*Sub-Committee.*—Joseph W. Richards, Chairman; Henry F. Keller, Samuel Sartain.]

(No. 2196.) *Hammer's Experiments in Long-Distance Phonographic and Telephonic Transmission.*—William J. Hammer, New York.

The experiments here referred to were made by Mr. Hammer in connection with a lecture delivered before the Franklin Institute, on February 4, 1889, and consisted in transmitting the sounds of the human voice, both talking and singing, and of instrumental music, between New York City and the lecture hall of the Institute, through 104 miles of Long-Distance Telephone Company's metallic circuit, 98 miles of which was overhead or underground, and the remaining 6 miles under water.

The experiments involved several new and ingenious combinations of telephonic and phonographic transmission.

The investigators to whom the subject was referred find, with other things, that the author at an earlier date above named, had successfully demonstrated the possibility of employing the phonograph and the land-operating telephone for use as a relay and repeater in the telephonic transmission of sound over long-distances. The Scott award is recommended to the author for this early demonstration. [*Sub-Committee.*—L. F. Rondenella, Chairman; Carl Herring, Arthur J. Rowland, Thos. Spencer.]

(No. 2197.) *Governor System.*—Francis M. Rites.

ABSTRACT.—This system is covered by a number of patents (1886–1900) granted to applicant. The system investigated involves a method of designing the governors so as to realize the advantage to be gained in utilizing inertia to assist centrifugal force in shaft-governors and incidentally make proper provision for such disturbing influences as friction in the joints, the lack of gravity balance, and the friction and inertia of reciprocating parts.

Generally speaking, the patented inventions in this field have aimed at accomplishing one or the other of these functions, frequently at the expense of simplicity. The Rites Governor System has its value more in the method adopted in designing the governors so as to condense all these functions in a single governing mechanism.

The report makes special reference to one of Rites' patents (No. 534,579, February 19, 1895), which contains as its essential elements the combination in a single-weight shaft-governor of an inertia weight and centrifugal weight integrally formed.

The body of the report bears upon the system of calculation or design developed by Mr. Rites by which he can clearly predetermine the performance of the governor as to regulation, rapidity of action and stability.

For the details the reader is referred to the report. The award of the John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—A. Falkenau, Chairman; H. W. Spangler, Hugo Belgram.]

(No. 2198.) *Trolley Wheel.*—C. H. Bierbaum, Buffalo, N. Y.

ABSTRACT.—This device (patented) consists of two stamped annular steel flanges and a central ring of copper forming the tread, held together by suitably casting within the central opening a hub with projecting flanges, which on cooling grips the parts, firmly holding them together. The chief advantages are cheapness of manufacture, on account of the small amount of copper used, and lightness.

The objectionable features in the use of steel flanges are the injurious effects of the hard steel on the trolley wire, which will be aggravated by the arcing which inevitably occurs, and the liability to accidental injury from striking an obstruction.

The novelty of the invention appears to consist in the method of holding the parts together by the cast hub. No award. [*Sub-Committee.*—Lucien E. Picolet, Chairman; Wm. E. Bradley, Charles C. Heyl.]

No. 2199.) *Storage Battery.*—Wm. Bell.

(An advisory report.)

No. 2204.) *Improvements in Screw-Jacks.*—D. Glenn, Del Rio, Texas.

ABSTRACT.—This invention is the subject of letters patent of the U. S., Nos. 610,044-5, Nov. 30, 1901, to applicant.

(An advisory report.)

(No. 2208.) *Automatic Revolving Time-Table.*—Johnston.

(An advisory report.)

No. 2217.) *Safety-Brake for Trolley Lines on Steep-Grade Roads.*—H. C. Moyer, W. M. Blooming, Glen, Pa.

(An advisory report.)

The following reports were read and held over for final action at the next meeting, viz.:

(No. 2181.) *Enclosed Arc Lamp.*—C. J. Toerring, Philadelphia.

(No. 2183.) *Stencil Machine.*—Andrew J. Bradley, St. Louis, Mo.

(No. 2185) *Process of Treating Tool Steel.*—Fred'k U. Taylor, Maunsel White, Bethlehem, Pa.

(No. 2195.) *Single-phase Electric Motor.*—Wagner Electric Company, St. Louis, Mo.

(No. 2205.) *Automatic Electric Brake Motor.*—Crocker-Wheeler Electric Company, Ampère, N. J.

(No. 2206.) *Turret Lathe.*—Julius Wilhelm Pittler, Leipzig-Gohlis, D. R.

The annual election of the Committee resulted in the choice of Mr. Thomas P. Conard for Chairman, for the coming year.

The Secretary reported that the Committee's proposal for the issue of a diploma to accompany the award of the Edward Longstreth Medal of Merit had been approved by the Board of Managers of the Institute; and that for a similar diploma to accompany the Scott award, the Board of Directors of City Trusts had given its sanction. W.

SECTIONS.

(*Abstracts of Proceedings.*)

ELECTRICAL SECTION.—*Stated Meeting.* Thursday, February 20th, 8 P. M. President Morris E. Leeds in the chair. Present, 32 members.

The following officers were elected to serve for the current year, viz.: President, Thomas Spencer; Vice-Presidents, Joseph Richards, Geo. T. Eyanson; Secretary, Richard T. Binder; Conservator, Dr. Wahl.

The meeting was devoted principally to a communication from Prof. Arthur J. Rowland, who presented some notes of his observations of the behavior and efficiency in service of the American type of Nernst Lamp. The speaker's remarks were quite informal, and indicated that while the lamps gave a fine light, there was still room for improvement in certain details of construction before they could be said to be completely adapted for commercial service.

Mr. J. D. Pierce exhibited and described a new type of miniature receptacle for incandescent lamps, which embodies some novel features of construction.

RICHARD L. BINDER,
Secretary.

PHYSICAL SECTION.—*Stated Meeting* held Wednesday, February 26th. Dr. A. S. Mackenzie in the chair.

Dr. Wm. S. Franklin, of Lehigh University, Bethleham, Pa., presented a communication on "Poynting's Theorem," which was illustrated with the aid of lantern slides.

The subject was discussed by Drs. A. T. Mackenzie, Geo. F. Stradling, H. M. Lloyd, Prof. Geo. A. Hoadley and Mr. Jesse Pawling, Jr.

The thanks of the meeting were voted to Dr. Franklin Adjourned.

JESSE PAWLING, JR.,
Secretary.

CHEMICAL SECTION.—*Stated Meeting* held Thursday, February 27th. Mr. Lyman F. Kebler, President, in the chair. Present, 15 members.

Mr. Wm. H. King, of the Chemical Division of the U. S. Dep't. of Agriculture, read the paper of the evening on "The Estimation of the Carbohydrates with especial Reference to Food Products." The paper was dis-

cussed by Messrs. L. F. Kebler, M. I. Wilbert, C. A. Hexamer, Dr. H. F. Keller and the author. (The paper will be published in the *Journal*).

The meeting passed an unanimous vote of thanks to Mr. King for his admirable communication, and adjourned.

WM. H. WAHL,
Secretary pro tem.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, March 6th. President Dr. Henry Leffmann in the chair.

It was announced that the paper originally intended for this meeting, *i.e.*, "The Microscope in the Determination of Geological Age," by Mr. Lewis Woodman, had, for unavoidable cause, been postponed.

Dr. Leffman presented a communication entitled "Recent Applications of the Microscope to Sanitary Questions." The subject was illustrated with photo-micrographs projected on the screen, and by means of the table microscope.

Mr. Fred. E. Ives read a communication on "Photography as a Means of Recording Scientific Phenomena," and presented an ingeniously contrived camera-box, adapted for use with the microscope. In demonstrating the possibilities of this device, Mr. Ives also showed a very complete and compact folding microscope of his devising.

Mr. Ives proceeded to illustrate the subject by projecting some photo-micrographs, showing the high-class work that could be done with very little effort. Adjourned,

MARTIN I. WILBERT, *Secretary.*

ELECTRICAL SECTION.—*Stated Meeting* held Thursday, March 20th. President, Thomas Spencer, in the chair.

Mr. Caryl D. Haskins, of the General Electric Company, read the paper of the evening, on "Electrical Measuring Instruments."

The speaker dealt with such electrical measuring instruments as are used in commercial practice—both instruments of position (as switchboard instruments), and portable instruments.

The paper constituted a practical treatise on the various limiting conditions which surround the use of instruments of this class in various branches of the art, for varying purposes, and dealt extensively with the principles which have been resorted to, to achieve the desired end under these varying conditions.

Initial accuracy and permanence of same, dead-beat qualities, character and distribution of scale, influences due to external causes, etc., were dealt with and analyzed in relation to the form of physical structure used in the coersive mechanism.

Mr. Haskins' paper was illustrated with lantern slides, embodying both photographs of instruments and numerous diagrams. The subject was discussed by Richard L. Binder, Prof. Arthur J. Rowland, Carl Hering and the author.

At the close of the discussion the meeting passed a vote of thanks to Mr. Haskins for his interesting and comprehensive treatment of the subject.

RICHARD L. BINDER, *Secretary.*